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TRANSACTIONS

C434
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OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

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Number Thirteen

MEETING OF OCT. 31, NOV. 1, 2 and 3, 1921

BUFFALO, N. Y.

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ERRATA

Formula on following pages should read:

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$$L = \frac{\pi \cdot 2.75^2 I}{4\ d^2} = 5.95\ \frac{I}{d^2}$$

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4. VISIBILITY (V_λ) of radiation of a particular wavelength

Page 77

$$b_F = \frac{dF}{dS} \qquad (2)$$

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The approximate formula is $\frac{Nx}{B_0} = \frac{\pi}{4S^2} - \frac{\pi}{2S^2} - \frac{f}{u}$,

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$$B_0\ (\text{min.}) = \frac{E_x\ (\text{min.})}{t \cdot Z} \times \frac{1}{W_v} \qquad (15)$$

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EXTRACTS FROM BY-LAWS

Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion-picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

Qualifications

Active Member—An Active member shall not be less than 25 years of age and shall be:

(a) A motion picture engineer by profession. He shall have been in the practice of his profession for a period of at least three years and shall have taken responsibility for the design, installation or operation of systems or apparatus pertaining to the motion picture industry.

(b) A person regularly employed in motion picture or closely allied work, who by his inventions or proficiency in motion picture science or as an executive of a motion picture enterprise of large scope, has attained a recognized standing in the motion picture art. In the case of such an executive, the applicant must be qualified to take full charge of the broader features of motion picture engineering involved in the work under his direction.

Associate Member—An Associate member shall not be less than 21 years of age and shall be:

A person who is interested in or connected with the study of motion picture technical problems or the application of the same.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance and transfer fees, payable on admission to the Society, or upon transfer, are as follows: Admission to grade of Active member, $35.00; admission to grade of Associate member, $10.00.

The transfer fee from Associate grade is the difference between the admission fee, or $25.00.

The annual dues are as follows: For Active members, $20.00; for Associate members, $10.00.

President's Address

WE are now entering the sixth year of our existence. Back in 1916, Mr. C. Francis Jenkins had the vision of a need for technical standardization in the motion picture industry and we are here assembled as the Society of Motion Picture Engineers because Mr. Jenkins had the courage to act on his convictions. The need for such an organization as we now have is evidenced in the wonderful growth of our organization and the wide scope of our activites. The first six sessions which were held were of two-day duration. The older members will recall that in those days we had a difficult problem to prepare a program to fill two days. We then started to expand and for the next three sessions we ran under a schedule of three days. We broadened still further until the last three sessions have necessitated four days, and we have no difficulty getting papers of merit to fill our program; in fact, we have found it necessary to curtail discussions in order to keep the scheduled program.

The time has now come when I feel that we should demand the recognition in the motion picture industry to which we are unquestionably entitled. We started out on a small scale and have worked effectively and efficiently, and have achieved that of which we are justly proud. Our efforts are affecting the industry in all its various branches from the studio to the screen and, therefore, why should we not demand recognition from those who have and will benefit from our activities? Our usefulness to the motion picture industry has been well established.

The world is depending more and more upon the use of motion pictures, not only in the entertainment field but also practically in every field of activity; educational, industrial, mechanical, medical, etc. The return to normal is going to open new developments and possibilities and we must be ready to meet the newer and greater responsibilities which we will be called upon to assume. It is the opinion of those closely affiliated with financial and commercial interests that the business depression has reached the bottom and that we are now on the slow climb back to normal conditions. The depression during the past year, naturally, had an effect on our work. Funds not being available to the same extent as in more prosperous periods, research and development work has not advanced very rapidly.

Every technical branch of the industry should be represented in our Society. Each branch should cooperate, giving freely of its best, in exchange for the best of others. In so doing, we will recognize the value of gaining by giving, and failure to recognize this will work to our disadvantage. It is necessary that we have an exchange of ideas and opinions from individual members. This will bring about a better understanding of our aim and purpose.

In several of my previous messages to you, I have tried to point

out the importance of more action on the part of the Standing Committees. Committees are the means of arriving at a solution of common problems and they are, or should be, made up of those members who are the best informed on subject matters pertaining to committees of which they form a part. A few of our committees have done splendid work and have gotten results, but these are the exceptions. There is much to be done and if those who are honored by appointment on committees during the coming year will make an analysis of the tasks which have been assigned to them, they will find plenty to do and their efforts will increase the efficiency of the Society. Why not try to work out a plan for each committee to get together at least once between our regular semi-annual sessions?

After a very careful analysis of our membership, and in accordance with your instructions, a Standardization Committee has been appointed by your President from a list of suggestions by individual members of your Board of Governors. The Standardization Committee is going to be the most important committee you will have and your cooperation with this committee and its deliberation will have a decided effect on the industry.

At this meeting you will select your officers for the coming year. In line with your approval and in order to eliminate any possibility of politics entering into the nomination for officers, your Board of Governors now and in the future, will act as a nominating committee for a slate for the elective offices. The report of the nominating committee is by no means final and additional suggestions will be welcomed. With the growth and extension of the Society, the officers will carry greater responsibilities and therefore selections must be made with great care.

I would like to take this occasion to make mention of our printed transactions. Have you realized that our transactions to date, contain articles relative to approximately every technical branch of the motion picture industry? Those who are just affiliating with our Society should avail themselves of the opportunity of obtaining copies of our earlier transactions. The Washington transactions are a valuable addition to our proceedings. On behalf of the Society, I wish to express appreciation to those who were responsible for its development and formation:—those who presented papers, those who enlarged the scope of the papers by discussion and also the Committee on Papers and the Committee on Publications. A large circulation of our transactions outside our membership is highly desirable as our transactions are the means of indicating our activity to the industry at large, and also a large circulation makes the advertising space more valuable. The sale of advertising space is one of the means of obtaining funds whereby we are able to carry on our activities. Not only should each individual firm represented in the Society use our transactions as an advertising medium, but we should also get advertising space from those in the industry who are not affiliated with us.

An excellent program has been prepared for this meeting by the Committee on Arrangements cooperating with the Committee on

Papers. Aside from the technical papers and the discussions, the Committee on Arrangements have made such provisions that our time will be well occupied. I am sure that our appreciation will amply repay them for their efforts.

In closing, I woud like to remark that your officers have endeavored to guide your activities to the best of their abilities. Matters of importance have been discussed and decided at meetings of your Board of Governors which have been held periodically, and our deliberations are indicated in the minutes of the Board of Governors which the Secretary has or will read to you. There has not been a single note of discord and our actions have been unanimous. I wish to express my sincere personal appreciation to the officers, those comprising the various committees, and the other individual members of the Society for the cooperative spirit shown and the help which has been given me during the three years in which it has been my pleasure to serve as your President, and I bespeak the same assistance and cooperation to those whom you will select to office during the coming year. The meeting is now open and I trust that each of you will take advantage of the opportunity afforded you by constructively discussing the very able papers which will be presented for your consideration.

H. A. CAMPE.

Buffalo, N. Y., October 31st, 1921.

1922 SPRING CONVENTION

May 1, 2, 3 and 4

Boston

Headquarters, Bellevue Hotel

The Illumination with Small and Large Condensers

By W. E. Story, Jr.

THE present paper is the outgrowth of the discussion in connection with the paper on condensers at the last meeting of this society. The method previously described has been applied to measuring the efficacy of small condensers as compared with the standard 4.5 inch, for sources and projection lenses of a variety of sizes. A graph showing the relation between brilliancy of incandescent filaments and lamp life has been added.

The apparatus used was essentially that previously described in these transactions ([1]), except that the use of a more sensitive cell permitted the return ([2]) to an opal glass (O, Fig. 1), instead of a condenser beyond the dummy projection lens (P). The cell (C) was placed 6 inches from O and the inside of the cell box painted white to insure a deflection depending on the quantity of light falling upon the opal glass, and not on the particular part of it illuminated. This substitution allows of a simpler unit of deflection, as will appear later.

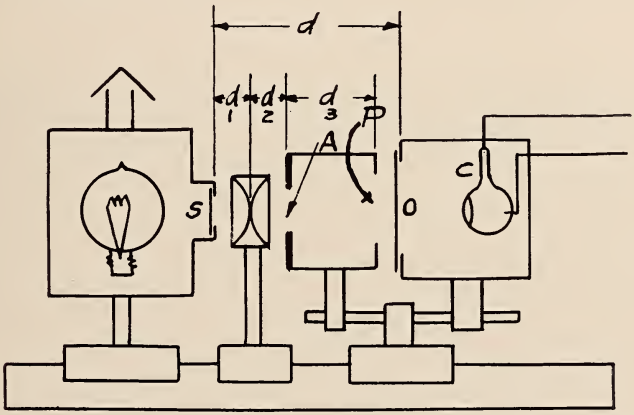

Fig. 1—Diagram Showing Arrangement of Apparatus Used in the Investigation.

As before 5.5 inches was selected as the distance (d_3) between the Standard aperture plate (A) and projection lens opening (P). The openings used were 2.5 inches, 2 inches and 1.5 inches. In the case of the Safety Standard aperture, d_3 was chosen as 3.75 inches and openings of 2 inches, 1.75 inches, 1.5 inches, 1.25 inches and 1 inch were employed. As before, these openings were simply holes cut in thin brass plates, and accordingly all the measurements of illumination, referring as they do to that light passing thru these holes, must be interpreted as light delivered to the projection lens. Accordingly, to find the light on the screen, these values must in each

case be multiplied by the efficiency of the projection lens used—that is by the proportion of the light it brings to a focus, to that falling upon it from the aperture.

Three small condenser combinations were compared with the 4.5 inches plano-convex previously used (loc. cit.). Their approximate diameters and focal lengths were as follows:

	Diameter	*Focal Length*
Condenser No. 1	1¼″	⅞″
Condenser No. 2	1 13/16″	1 5/16″
Condenser No. 3	1¼″	⅞″

That d_1 with which the greatest deflection could be obtained for each combination of source, condenser, aperture and projection lens, was determined in each case without making a plate, but by noting the maximum galvanometer deflection as d_2 was changed. For each condenser-aperture combination a plate was then made, each curve of which represents a combination of source and projection lens size, made with the value of d_1 found as described. These plates are shown in Figs. 2 to 9. The curves are all numbered, and the various combinations indicated under their numbers in Tables I and II. *The values of* d_1 *are here given in sixteenth of an inch.*

As will be seen, there is but little change in d_1 for any given condenser, for changes in size of source or projection lens. This means, of course, that for maximum illumination the "image" of the source produced by the condenser should be in approximately the same place—that is, in the projection lens for the small condensers, and the aperture plate for the large.

The ordinates of the curves are not now given in terms of the maximum possible illumination with a source of given intrinsic brilliancy ([3]). Instead, after all the curves showing the variation of illumination with change of condenser-aperture distance (d_2) were made, the condenser (C), aperture (A) and projection lens (P) were removed and the source increased to 1 inch on a side. This source was placed 8 inches from the opal glass (O) of the photoelectric cell assembly and the deflection of the galvanometer thus obtained. The cell assembly was then moved back slowly from the source, this deflection, of course, decreasing approximately as the square of the distance (d). The curve traced out in this way is designated by R in the figures. It will be noted that the scales of d and d_1 are the same, the d zero has been moved along 7 inches, to bring the R curve on the plate.

The opal glass of the cell assembly was 2.75 inches in diameter. Accordingly, the light in lumens falling on it from the 1 inch source was approximately

$$L = \frac{\pi . 2.75^2 I}{4\, d^2} = 5.95 \frac{I}{d^2}$$

where d is the distance from the source (S, Fig. 1) to the opal glass (O) and I the intrinsic brilliancy of the source. Assuming convenient values of $\frac{L}{I}$, corresponding values of d can be cal-

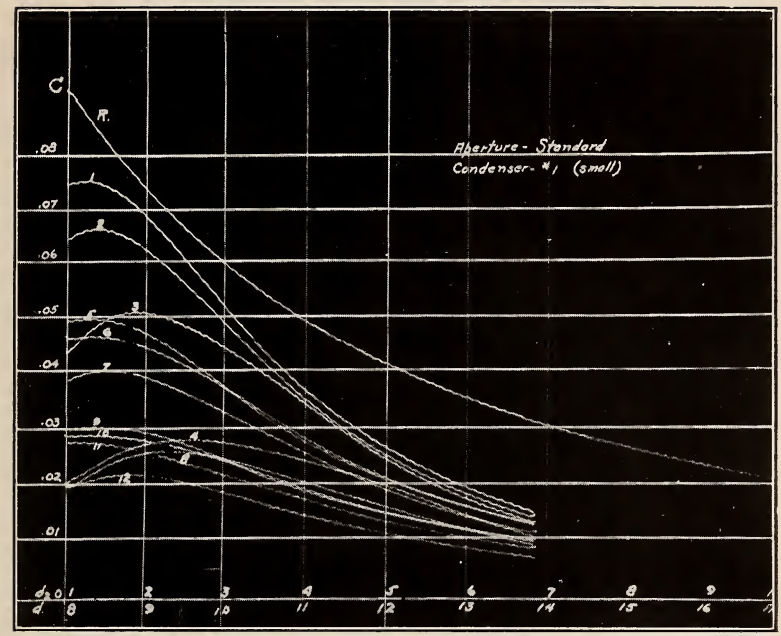

Figure 2

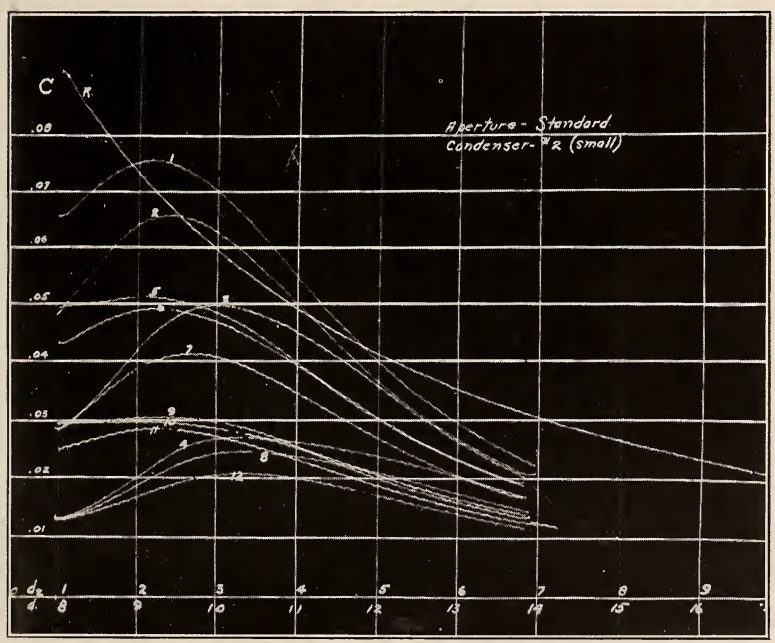

Figure 3

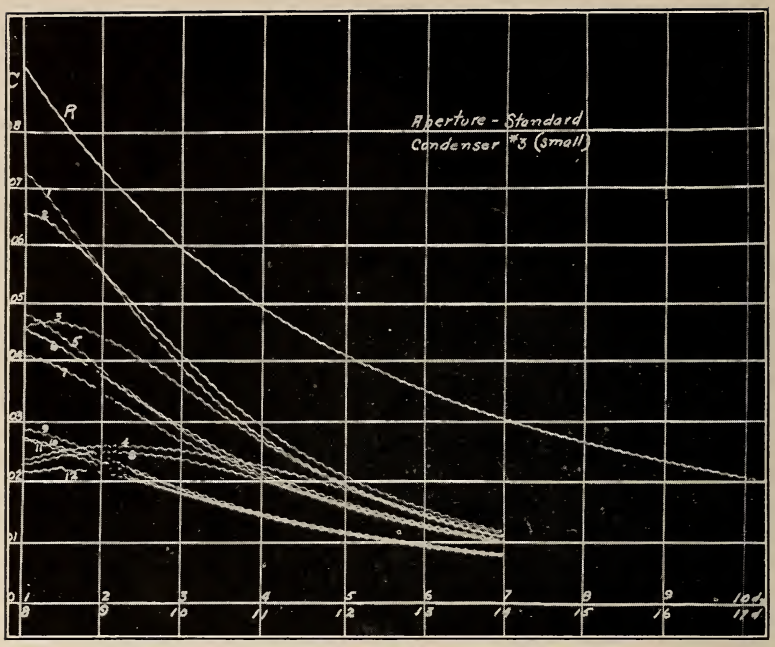

Figure 4

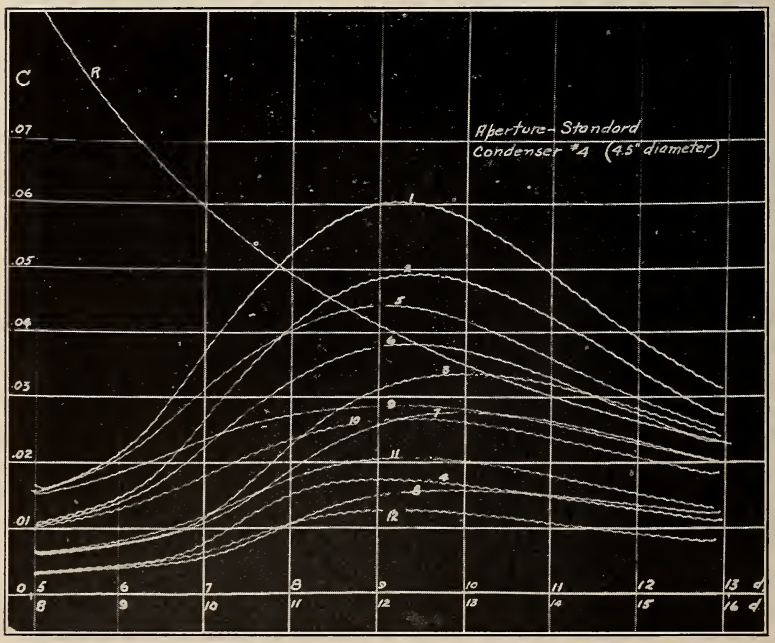

Figure 5

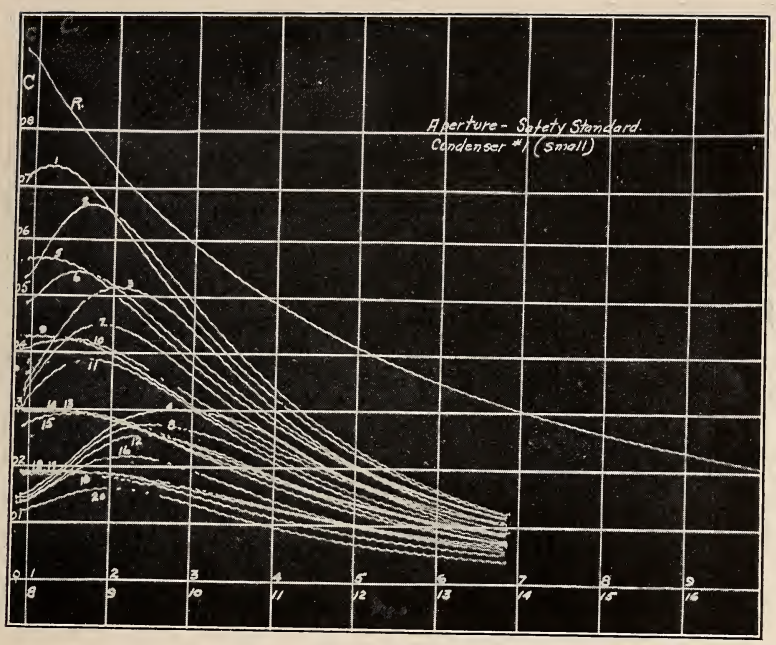

Figure 6

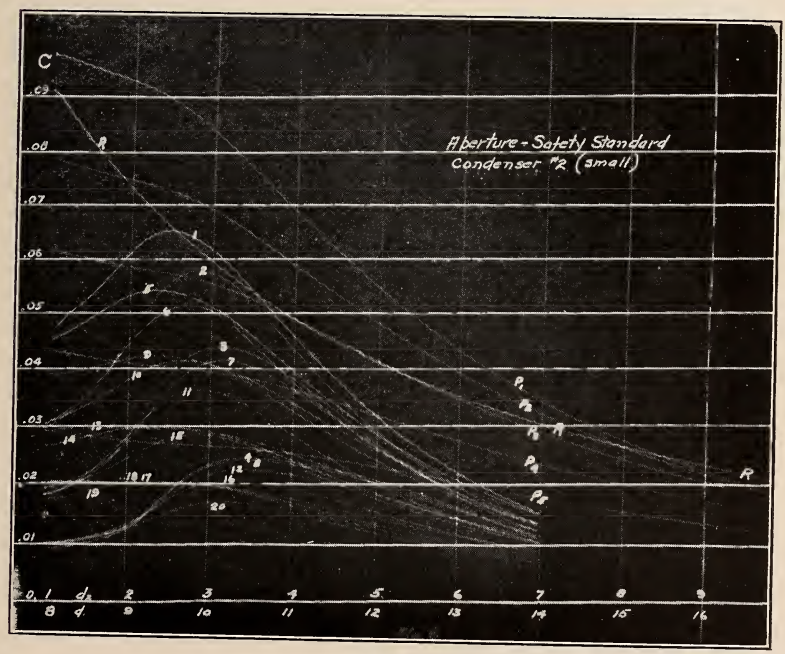

Figure 7

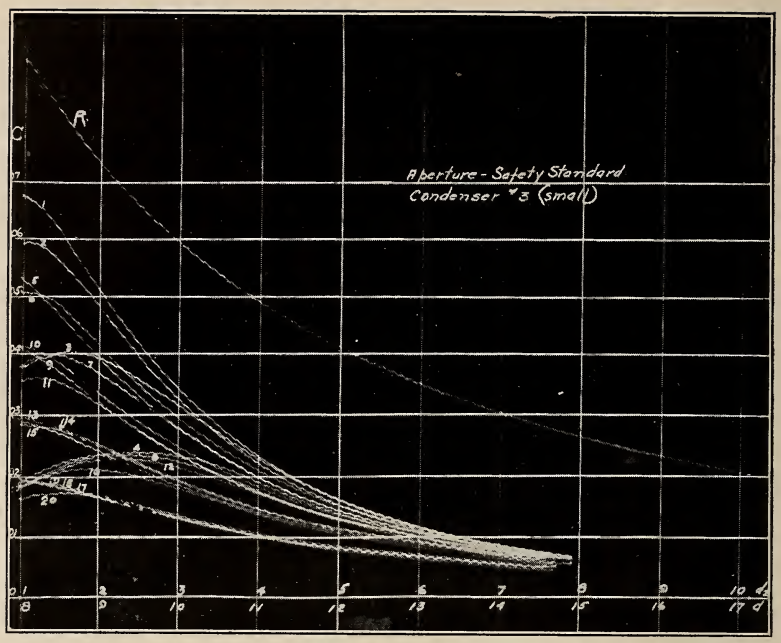

Figure 8

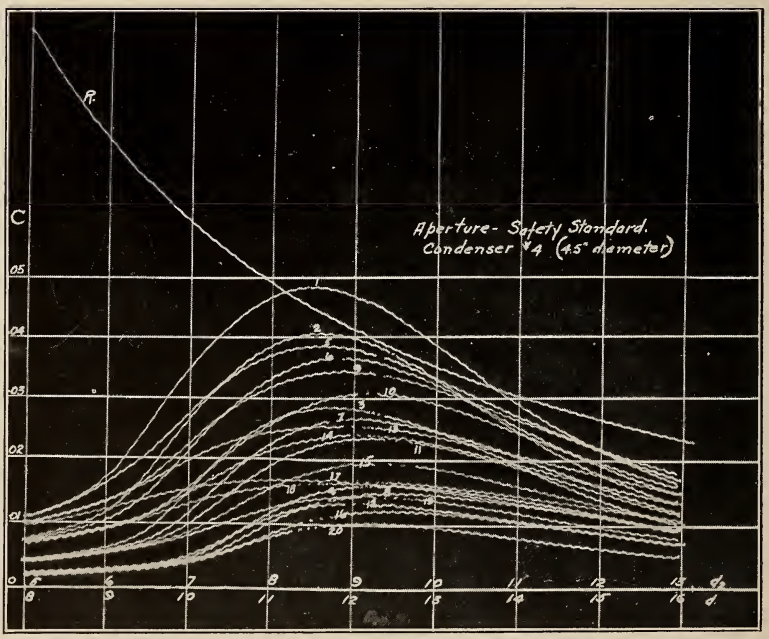

Figure 9

culated. If thru the points of the R curve having these values of d, ordinates be drawn, deflections represented by these ordinates will have the assumed values in lumens of the light falling upon the opal glass of the cell, divided by the intrinsic brilliancy of the source—or, since the lumens are proportional to the brilliancy—the lumens per unit brilliancy. Since the source brilliancy was the same for all the curves, the ordinates chosen in this way give also the lumens delivered to the projection lens per unit intrinsic brilliancy of the source.

TABLE 1—MAXIMUM VALUE, C, OF ILLUMINATION FOR STANDARD APERTURE

Focal Length Projection Lens 5.5″

Curve Number	Projection Lens Diameter	Source Side	Fig. 2		Fig. 3		Fig. 4		Fig. 5	
			d_1	C	d_1	C	d_1	C	d_1	C
1	2.5″	.5″	14	.0754	22	.0755	16	.0722	80	.0604
2	2.5″	.4″	14	.0651	22	.0656	18	.0650	80	.0493
3	2.5″	.3″	14	.0507	22	.0496	19	.0470	78	.0334
4	2.5″	.2″	14	.0280	22	.0270	15	.0260	80	.0175
5	2″	.5″	14	.0498	22	.0513	16	.0481	80	.0441
6	2″	.4″	14	.0460	22	.0490	16	.0452	78	.0380
7	2″	.3″	14	.0400	20	.0412	16	.0410	78	.0281
8	2″	.2″	14	.0270	22	.0243	16	.0250	79	.0160
9	1.5″	.5″	14	.0301	22	.0305	16	.0290	80	.0289
10	1.5″	.4″	14	.0291	21	.0297	16	.0279	78	.0270
11	1.5″	.3″	14	.0276	21	.0286	16	.0278	80	.0210
12	1.5″	.2″	14	.0215	21	.0208	16	.0223	80	.0123

This method of evaluating the deflection avoids all question of the proportionality of deflection to light falling upon the cell. That these two quantities are closely proportional, however, is shown by the equi-spacing on the plates of the lines calculated for equal illumination differences.

In Tables 1 and 2 are given the maximum values of the illumination (C) in lumens per unit brilliancy for the various combinations of source sizes, and projection lens diameters represented by the different curves of Figures 2 to 9.

Summaries of Tables 1 and 2 will be found in Figures 10 and 11 respectively. The relation between C and source side is here plotted for different diameters of projection lenses as indicated.

TABLE 2—MAXIMUM VALUE, C, OF ILLUMINATION FOR SAFETY STANDARD APERTURE.

Focal Length Projection Lens 3.75″

Curve Number	Projection Lens Diameter	Source Side	Fig. 6		Fig. 7		Fig. 8		Fig. 9	
			d_1	C	d_1	C	d_1	C	d_1	C
1	2.0″	.5″	14	.0739	25	.0651	18	.0675	84	.0483
2	2.0″	.4″	14	.0669	26	.0580	18	.0595	84	.0402
3	2.0″	.3″	14	.0515	26	.0441	17	.0404	80	.0286
4	2.0″	.2″	14	.0300	25	.0249	18	.0240	84	.0160
5	1.75″	.5″	13	.0564	25	.0543	18	.0535	82	.0385
6	1.75″	.4″	14	.0547	26	.0516	18	.0507	80	.0362
7	1.75″	.3″	14	.0450	26	.0415	18	.0400	82	.0265
8	1.75″	.2″	14	.0271	25	.0240	19	.0235	79	.0151
9	1.5″	.5″	12	.0425	23	.0421	18	.0406	80	.0346
10	1.5″	.4″	14	.0417	27	.0411	18	.0416	83	.0310
11	1.5″	.3″	14	.0389	27	.0362	18	.0360	81	.0232
12	1.5″	.2″	14	.0252	25	.0227	18	.0230	79	.0132
13	1.25″	.5″	14	.0298	23	.0300	18	.0297	80	.0253
14	1.25″	.4″	14	.0296	25	.0298	18	.0290	80	.0239
15	1.25″	.3″	14	.0292	25	.0288	18	.0294	80	.0198
16	1.25″	.2″	14	.0219	25	.0209	18	.0212	79	.0119
17	1.0″	.5″	13	.0194	25	.0204	18	.0196	80	.0170
18	1.0″	.4″	14	.0194	26	.0204	18	.0196	80	.0165
19	1.0″	.3″	14	.0185	26	.0204	18	.0196	80	.0145
20	1.0″	.2″	14	.0169	25	.0180	18	.0171	80	.0103

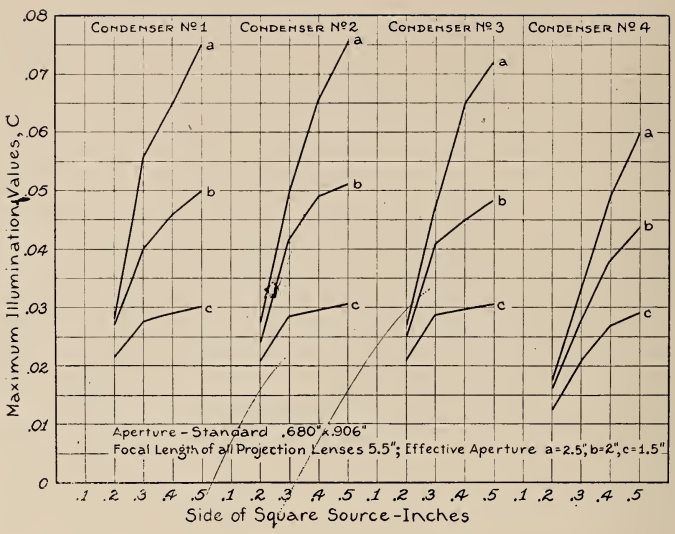

Figure 10

As noted in the previous work (loc. cit.) an increase of source size above a certain size, does not increase illumination materially unless a large projection lens is used also. Since these plates were made, it has been learned that 2-inch lenses (those represented by the curves d in Fig. 11) cannot be made of as short a focal length as 3.75 inches with satisfactory definition. In fact, it is only by the use of an aspheric surface on one of the components, that a lens of 1.75 inches

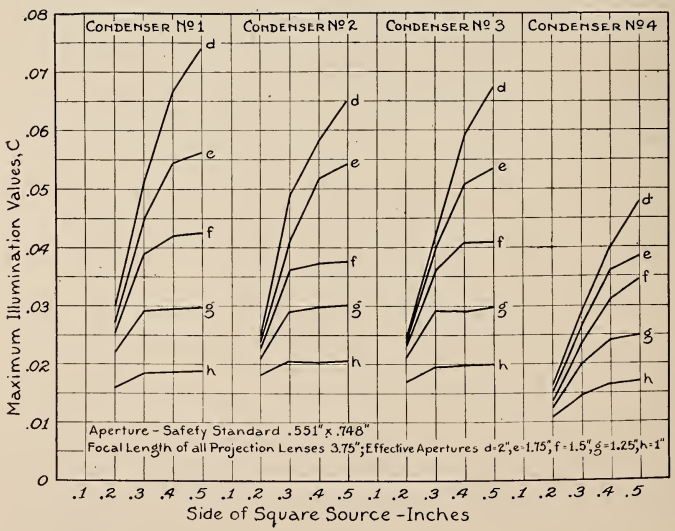

Figure 11

diameter can be obtained. This is due to the increase of the angle at the projection lens subtended by the film at these small distances. Accordingly, the curves f are the highest ones of Fig. 11 that can now be considered as of interest commercially. Development along the line of lenses of smaller f : value is recommended as offering the best chance at present, for increase of illumination in this type of projection.

In these experiments the 4.5-inch condenser has been used as a measure of quantity of illumination only, in order to connect the light given by the smaller condensers with that found previously with the plano-convex, meniscus and prismatic. It is, of course, impossible, as there shown, to use the plano-convex at the position of maximum illumination, as given in Figures 10 and 11, when using a source of ununiform brilliancy, such as an incandescent filament. If this 4.5-inch plano-convex is thrown so far out of the position of maximum light that it will give a screen uniform to the eye, then, according to the previous findings, we cannot get an illumination greater than about one-half that of curve a for a .5 inch source, by the use of any of the projection lenses now available. This gives, then, a practical value of C equal to .030 for the 4.5 plano-convex, using a standard aperture, a .5 inch light source, and a 2.5 inch projection lens of 5.5-inch focal length.

The small condensers, on the other hand, give an approximately uniform field at their positions of maximum brightness. However, for sources larger than .3 inches on a side, there are at present no lamps available in which the wall of the lamp bulb is so close to the filament that it can be brought to within that distance from the optical center of the condensers which gives the maximum illumination. There is another practical limitation. When using sources as high as .3 inches on a side, in a small bulb, the brightness of the source cannot be made as great as in the larger bulb lamps, if the life of the lamp is to be the same in the two cases. The greatest illumination thru a standard film aperture that can be obtained with the small condensers, is, then, perhaps .055, .05, and .047 respectively—and this with an expenditure of energy of but little more than one-third that required to give the .030 with the 4.5 inch plano-convex.

In the paper to which reference has already been made, one of the prismatic condensers (No. 3) gave 4 per cent more light than the plano-convex we are now using as a standard of reference; and, what is more important, at this point of maximum illumination the screen was uniformly lighted. Adding this 4 per cent to the maximum value of C for the large condenser of Figure 10, we get .062 as the maximum useful light obtainable with the prismatic condenser. It will be noticed, however, that for the small projection lenses this superiority of the prismatic over the small condensers is inappreciable.

It is possible that more light than this .055, .05, and .047 could be obtained by the use of the .5 inches source further from the condenser. However, since the .5-inch source of the 900-watt lamp sub-

tends a slightly smaller angle at the condenser when the lamp bulb is touching the condenser housing than is subtended by a .3 inch source at a distance of an inch, or less, as with condensers No. 1 and No. 3, there is no gain in the use of this lamp, apart from the higher brilliancy obtainable for any given lamp life. On the other hand, it will be observed from the tables that d_1 for condenser No. 2 is .137 inches, at which distance it would take a .39-inch source to subtend the same angle as the 900 watt lamp at 1.75 inches—or the 900-watt lamp should give, if close against the condenser, a value of C of about .065—a little better than the prismatic.

If the same relation holds between the prismatic No. 3 and the plano-convex in the case of the Safety Standard film aperture—a very reasonable assumption—the best uniform illumination obtainable with the prismatic condenser and the 1.5 inch projection lens, is about .035; whereas condensers No. 1, No. 2, and No. 3, with .3 inch sources in available bulbs, will give perhaps .039, .036, and .036. The substitution of the 900-watt lamp in a 2.5-inch diameter bulb will, as before, give these same values of illumination for condensers No. 1 and No. 3, while for condenser No. 2 the new source, being the equivalent of a .39-inch source at 1.37 inches will increase the illumination to .037. The use of a larger projection lens, as recommended above, will increase the value very materially, as shown in curves e and d. These, of course, are but approximate figures, based on apparently justifiable assumptions—one of which is that the intrinsic brilliancy of the sources are the same, and that the average brilliancy over any considerable part of any source is the same as that of any other considerable part. Such a condition obtains in the monoplane filament lamp, for example, where any considerable area contains approximately the same amount of filament, dark spaces, and, when using a mirror behind the filament, filament image.

Thus far, all the measurements of illumination have been given in lumens delivered to the projection lens (in the case of the motion picture set-ups) per unit of brilliancy. To determine the actual number of lumens on the screen this must be multiplied by the specific brilliancy of the source and by the efficiency of the projection lens.

As before, it seems best, when comparing condensers, to regard the efficiencies of the projection lenses as an entirely separate problem, involving, as it does, for each type of lens a factor practically constant for every size and type of condenser used. It has been shown before this Society ([4]), that the loss in projection lenses consists largely of the reflection losses—approximately 4 per cent. at each surface between air and glass. Absorption losses may bring this to 10 per cent. for each single lens or cemented combination. Knowing, then, the number (n) of such combinations in any lens, its efficiency $E = 9^n$ is easily calculated.

The specific brilliancy of the incandescent filament source as ordinarily used in projection is

$$I = A_1 i + A_2 mi = i\,(A_1 + mA_2)$$

TABLE 3—EFFECT OF CHANGE IN POTENTIAL ON 5.5 AND 30-AMPERE, 28-32 VOLT INCANDESCENT PROJECTOR LAMPS

Volts	Amps.	Watts	C P With Mirror 5.5-Ampere Lamp	I C P÷Area	Temp. °K	Approx. Life
30	5.59	168	710	7900	3000	100
33	5.87	194	950	10600	3100	32.1
36	6.17	224	1250	13900	3185	12.9
39	6.46	252	1600	17800	3270	5.6
42	6.74	283	1980	22000	3355	2.7
45	7.02	316	2490	27700	3435	1.2
48	7.30	350	2960	32900	3510	.6
			30-AMPERE LAMP			
23.5	26	611	2310	9240	3010	2090.
24.8	27	670	2890	11600	3067	1080.
26.9	28	753	3910	15600	3150	442.
28.4	29	823	4070	16300	3210	238.
29.9	30	897	5050	20200	3297	100.
31.8	31	987	5980	23900	3355	58.
33.5	32	1072	6960	27800	3445	26.
35.2	33	1161	7890	31600	3505	15.
37.1	34	1260	9000	36000	3565	9.

where A_1 is the proportion of the area the filament itself fills, A_2 the proportion filled by the image reflected in the mirror, i the average specific brilliancy of the tungsten, depending upon its temperature, emissivity, and shape, and m, the efficiency of the reflection, being

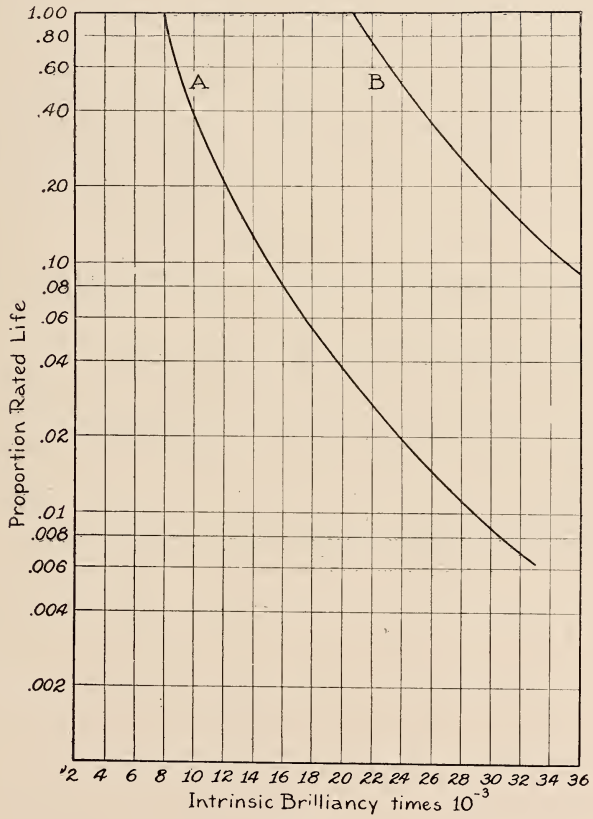

Figure 12

certainly lower than 65 per cent. or 70 per cent., because of reflection loss at the cylindrical bulb.

The calculation of I would be quite difficult, but its measurement for any given lamp is very easy. Of course the higher the temperature the greater the brilliancy, and since, in the majority of projection work, cost of power is not an important factor, the interest centers in the relation of brilliancy to the life of the lamp.

Table 3 shows the results of a rise of potential across (A) a 30-volt, 5.5 ampere monoplane filament lamp having the filament within a square .3 inches on a side and mounted in a 1.25-inch bulb: (B) a 30-volt 30-ampere monoplane filament lamp having the filament within a .5-inch square and mounted in a 2.5-inch bulb.

The volts, amperes, candle power and the temperature at 30 volts, were measured. The intrinsic brilliancy was calculated as indicated, and the temperature from lamp data. The life being inversely proportional to the rate of evaporation ([5]) could be calculated for any temperature, assuming a life of 100 hours at rated potential.

Figure 12 is a graph showing the relation between intrinsic brilliancy and life for the lamps as given above. The greater brilliancy for the same life due to the large diameter of wire in the 900-watt lamp will be noticed.

In conclusion, to illustrate the simplicity of the calculation from the data given, of lumens (Ls), there may be taken as an example an equipment consisting of the 900 watt motion picture lamp (B, Fig. 12) run at 30 amperes, a prismatic condenser, a standard aperture, and a 2.5 inch projection lens of 5.5 inch focal length. In this case, if the projection lens consists of four separate glasses.

$$L_s = I \times E \times G = 20200 \times 655 \times .062 = 820$$

Considering the roughness of this approximation, this value agrees very well with that found in practice. ([6])

([1]) Trans. Soc. Mot. Pict. Eng. No. 10, May, 1920.

([2]) Trans. Soc. Mot. Pict. Eng. No. 9, Oct. 1919.

([3]) The curves P_{1-5} from which maximum possible illumination was previously determined, are given in Fig. 7 for comparison.

([4]) "Absorption and Reflection Losses in Motion Picture Objectives." Kellner; Trans. Soc. Mot. Pict. Eng. Oct. 1920.

([5]) "Vapor Pressure of Metallic Tungsten." Langmuir; Phys. Rev. II, p. 329, Nov. 1913.

([6]) "Condenser Lenses for Theatre Motion Picture Equipment." Egeler; Trans. Soc. Mot. Pict. Eng. No. 12, May 1921.

Discussion

Dr. Kellner: Answering first a personal question by Dr. Story, whether lenses with as short a focal length as 3¾ inches and a free diameter of 1¾ inches are practical for motion picture projection and whether they should have been used in his tests, I may state that such lenses are really beyond the limit of commercial manufacturing possibilities at the present status of the art. The field of angle of a 3¾-inch lens taken diagonally across the aperture plate amounts to 18 degrees, which cannot be covered with that lens aperture without noticeable curvature of field and other aberrations at the margin of the field.

It may be of interest to know that we have designed and made two years ago, 3¾ inches f:2 projection lens in which we obtained a perfect flatness of field by the use of an parabolic surface on one of the components. Although this result represents a remarkable progress in the making of projection lenses such lenses are at present not to be considered as commercial possibilities.

Lenses with considerably greater equivalent focal length can be made without difficulty to cover the size of the aperture plate with an aperture ratio f:2. Equivalent focal lengths of about 5 inches with an aperture ratio f:2 have been made without the use of an aspheric surface, which cover the aperture plate as well as lenses of lower aperture.

Dr. Story's paper corroborates—as it seems to me—experimentally some of the statements which I made in my Cleveland paper, "On the Function of the Condenser in the Projection Apparatus," to which I have to refer for details.

An investigation of this nature will apply to the problem of the motion picture engineer only, when the comparisons are made at a location where the aperture plate may be placed in practice, i. e., somewhere in the cone between condenser and projection lens, where there is a section with an area of even light distribution large enough to cover the aperture plate.

Unless a spherically corrected condenser is used, such an area of even light distribution will be surrounded by a ring of greater intensity which is caused by the spherical aberration and which cannot be utilized for projection because it would cause uneven illumination on the screen.

However, I again like to draw attention to the fact that even if a spherically corrected condenser were used and the section through the cone at the aperture plate were evenly illuminated, considerable loss of light occurs by reason of the diaphragm action of the aperture plate. In case of the uncorrected condenser we have a combination of losses by spherical aberration and by diaphragm action.

Dr. Story: If I understand Dr. Kellner correctly, he means that even if you had a condenser having no spherical aberration—you

would even then not be able to get away from the diaphraming action of the aperture plate.

Dr. Kellner: If you extended your source

Dr. Story: If, with any condenser sufficiently large to cover the entire aperture, as seen from every point of the projection lens when these three units are in position you use a large enough source, you will then have as much light as you can ever get through that projection lens with a source of that intrinsic brilliancy, barring reflection and absorption losses. Of course, since the ordinary source is square, and the aperture plate is wider than it is high, the image must lap over the top and bottom of the aperture a little bit even with a perfectly corrected condenser, in order to get as much breadth.

Mr. Victor: I would like to ask Dr. Story a question. These tests, were they made under practical projection conditions? By that I mean, was all the flux passing through useful? Another thing you mentioned, that if the small condensers were used with a half inch source of illumination, the result would undoubtedly be superior, but that we unfortunately are unable to get such a large source in such a small shell as the small lamps would permit. But it is my impression that the 30 volt 165 watt lamp which I submitted to you did have practically a half inch source. I may be mistaken about that, but I would like to find out if I am right or wrong.

Dr. Story: That source, with its image in the spherical mirror, was 9/32 of an inch wide by 5/16 of an inch high. I would like to repeat one thing about the tests. No attempt was made to have a uniform screen. We were simply considering maximum possible illumination. Of course, you cannot use the 4.5 inch condenser focusing a source on the aperture plate, unless that source is a uniform source, but we had found before that the prismatic condenser gives more light than the plano-convex at its best; the prismatic giving you also a uniform illumination. In other words, the plano-convex was here used merely to tie up this experiment with the previous one in quantities, leaving out entirely the effect of imaging on the screen, which, of course, you are bound to get with the use of any incandescent filament focused on the aperture plate. Of course, if you are going to avoid with this particular large condenser, that image, you must focus then in your projecting lens or near it, and you are bound to get a very decided diaphragming by the aperture plate. But that is only in the case where you take something else into consideration than the total quantity of light in the condenser.

Mr. S. C. Rogers: I would like to say in regard to focusing the filament on the aperture plate, that in all the experiments and tests that we have made, both with the 4½″ diameter prismatic and plano-convex condensers, meniscus combinations and reflector combinations, we have found that the maximum light was never obtained when the filament was focused upon the aperture plate. This does not necessarily mean that the screen is uniform or usable, it means only that the image is focused somewhere else either inside or outside the objective lens, depending upon the focal length of the lens.

This applies to all the cases of condensing and reflecting systems that we have tried out.

Mr. Victor: It seems to me that the tests we have been interested in—at least I express my personal interest—is in the advantage of different condensing lens systems as used in motion picture machines for the purpose of projection. In other words, it is a matter of obtaining the most brilliantly illuminated screen image, and to me, with all due respect to Dr. Story's very painstaking data, I am not convinced we have this test until we get a screen test. Now, you may be able to put, by focusing on the aperture or elsewhere, a tremendous amount of illumination, but it is only that portion of illumination that gives us a clear, sharp well-defined image on the screen that we can use. The rest is a by-product which is like the squeals of the pigs in Chicago—we don't know what to do with it. (Laughter.) And I am still waiting for accurate information as to the relative merits between large condensers, prismatic condensers, and the small condensers of which I am personally an advocate.

Mr. Egeler: Dr. Story has called attention to the fact that the application of these fundamental data involves consideration of the extent to which the uniform source employed can be duplicated in a practical incandescent lamp; among the principal factors are the relation of the source size (wattage) to the bulb diameter, the ratio between the average brilliancy of the soruce area to the maximum corresponding to a given lamp life, and the effect of the non-uniformity of the source brilliancy on the screen illumination. The minimum spacing between the source and the condenser is dependent on the bulb size, which in turn is a function of the lamp wattage. For a monoplane filament the wattage of a square source increases approximately as the square of the side dimension. The size of the source and the screen illumination are therefore limited for the small condensers by the wattage which can be placed in a bulb which will allow the filament to be placed the desired distance from the condenser. This limitation, together with the lower permissible operating temperature for the small low-current sources, counteracts in part the advantages obtained with the theoretical source.

In applyping data such as have been presented, it has been found that the non-uniformity of the screen illumination resulting from the non-luminous areas between the lamp filament coils will require that source-condenser and condenser-aperture spacings be modified in order that the screen will be illuminated to a satisfactory degree of evenness. A choice is accordingly based on a compromise between the amount of light projected and the uniformity of the screen illumination. This is because increase in the size of the beam at the aperture is to be expected when the spacings are changed from the values for maximum light, and the amount of light reaching the projection lens as a result is decreased. The loss of light at the aperture is materially less for the small condensers with which the aperture can be placed close to the condensing lens.

Data obtained with lamps of limiting wattages for bulbs which can be used with the large and small condensers show that a much

greater percentage of the light emitted by the source will be projected to the screen with the small condensers than for the large; the maximum gain obtained is of the order of 50-60 percent. But the smaller source-condenser spacing permissible for the small condensers limits the wattage and light output of the lamp so that the light output obtainable for the smaller lamps is only about one-seventh that received from the largest sizes, and several times as much light can therefore be projected with the large condenser systems.

Mr. Victor: Dr. Story was good enough to imply a wish on my part to see an actual screen test. It looks to me as if it is not a matter of quantity but of quality when we talk about the screen. You may say that a singer has a voice whose volume is satisfactory, but I certainly would prefer quality of voice. The same way with a screen image. It is not a question of laboratory photometric tests when we want to see a motion picture, because we are not using that to see a picture. A picture in which too many aberrations occur in the light, focus and diffusion, would not be worth anything; you couldn't use it. It is a quality matter, after all, as far as I see it. I don't ask to see it on the screen; I accept other people's word for it. But it is a question of quality plus illumination, and all our tests should be based upon that idea.

Mr. Jenkins: In all these discussions and in this gathering of data, I take it that the other element, which is a very serious one—certainly one that should be given consideration in actual projection, and probably just what Mr. Victor had in mind—is the shutter and its location. I believe on all the machines, and we are stilll confined to shutter machines, all our shutters on all machines now in use are located beyond the objective towards the screen. Now, if you use a larger objective in order to get more gathering power at the aperture plate and use a larger source in order to get more light, immediately there is trouble with the present size of shutter—because it does cut down the light, with the larger objective you use. So that I quite agree with Mr. Victor that I should have been more edified, perhaps, if we had these tests that you gentlemen are so laboriously preparing for us, put through a common motion picture set-up. A shutter has a certain function. The only function it has is to throw away the light, and absolutely no other function. Now, how are we going to minimize that loss except by making the rotating disc larger; that is, to use a shutter of larger diameter. That is the ideal plan, but the large shutter is a nuisance. Each succeeding machine I have ever designed has had still larger shutters because of the saving factor of the large radius as it cuts across these big lenses. So that I should have been happy indeed if some data that takes into consideration that further factor, the shutter out in front of the lens, could have been given us. I don't know whether that is an invitation to Dr. Story to get busy and do it all over again, but really until we get that, a great deal of what you gentlemen have done is left to us to juggle with as best we may in order to get a machine that will still further approach the ideal that you

have set in front of us. So that if anyone takes this up again, I should certainly be happy if they would just try for a minute a rotating shutter out there in front of the objective; for that is the condition that confronts us, we who design motion picture machines.

Dr. Story: I thought that I had made clear to Dr. Kellner that we used the 4½-inch condenser simply to tie in these experiments with the experiments which we had made before. In the previous work we had found that you could not use the plano-convex condenser—large plano-convex condenser—in any such position as to give it its maximum illumination efficiency without getting a badly striated screen. That is certainly the great advantage of the use of the prismatic condenser when using a source of ununiform illumination. The introduction of this 4½-inch plano-convex condenser was not in any way to indicate the *useful* light which it could give, but merely to show how the other condenser, which is not, perhaps, as much of a standard institution, compares with the small condensers.

Mr. Jenkins suggets our taking into account the shutters. If, as he says, large shutters are a disadvantage merely because they are cumbersome or a nuisance, I should say it was very much easier to overcome that nuisance than to go through this work again. (Laughter.) I cannot help feeling that the rest of the machine should be designed, even if it is more cumbersome, in such a way as to use, to the last ray, any light which the optical apparatus or the source can furnish, because we are close to the theoretical limits in both of those parts of the apparatus at least at present. There are certain well recognized limits beyond which no amount of cumbersomeness will allow us to go. If all possible light is desired, then it seems to me we ought to try for that larger shutter; if not, use a smaller projection lens.

Mr. Rogers: A few remarks in regard to what Mr. Egeler has just said. He said, I believe, that the small diameter condenser system is about 50 per cent. more efficient than the large, that is, a ratio of 1½ to 1. Now, the large size lamp, 30-ampere, 900-watts, such as is ordinarily used for the large projectors, will give about 4½ times the total lumen output of the 4-ampere, 50-volt lamp, such as is used with the small projectors. In other words, there will be about three times the screen illumination with the large diameter condenser and 30-ampere lamp than with the small diameter condensers and 4-ampere lamp.

The 4-ampere lamp, however, is operating at about a 20-hour life. If we operate the 30-ampere lamp at the same 20-hour life we will get between five and six times as much screen illumination as we do with the 4-ampere lamp.

Mr. H. P. Gage: This discussion has certainly been carried on in a most illuminating and instructive way. I do not know as I can add much to it. It seems to me that the question being discussed is whether better results can be obtained with a small condenser placed close to the aperture plate, which, of course, involves the light source being placed close to the condenser, as against having a large

condenser placed at a distance from the aperture plate with a light source, a bulb, so big that it cannot be placed right up next to the condenser. If we could always work with small light sources in small bulbs with small condensers close to the aperture plate, and not get into trouble with the fire underwriters, and not burn up the film, we would get good results with the small condensers. It is possible, however, by proper design, to use a large condenser and get approximately the same, or possibly slightly greater efficiency. The really important point is that with the large condenser we are not limited to the size lamp which can be gotten into a T-10 bulb and we can use a 900-watt lamp; for instance, instead of being limited to a 200-watt lamp.

We have made some experiments recently with more small or corrugated condensers than we have previously made. I do not wish to state the final conclusions, because we have not reached those yet, but one very noticeable thing was that with the small condenser—I think it was a 3-element condenser—there was very little less of light between the condenser and the aperture plate, but the total light flux originally incident on the condenser was not as great as is possible to get with the corrugated condenser. On the other hand, the corrugated condenser, receiving originally a greater light flux, delivered a large circle of light, and a lesser proportion was able to get through the aperture plate. In spite of this disappointing result the screen brightness was found to be 10% greater with the corrugated condenser, which is largely attributable to the fact that the system made up of two or three separate lenses has a ten per cent extra light loss for each separate lens, whereas the corrugated condenser consists of but one lens.

Mr. Denington: I just wanted to add one or two words in this discussion. We are talking about various condenser systems and how to get the light on the screen. In order to get the light on the screen we have to start with the light source, and the fact has been brought out partially that it is impossible to get a large amount of light on the screen unless we start with considerable light. We lose some all the way along. If we adopt any optical system which, by its smallness, limits the light source, then we are limiting the very starting point, and we certainly are going to get into trouble. That is, we can get only a limited effect, even though we might save a considerable percentage over some other larger system. For this reason I would like to have those who are working on this problem keep in mind the fact that it may be necessary and desirable to use even larger light sources than at present. There is a tendency to use arc lamps for higher power, and the heat intensity of these will probably make it necessary to use larger spaces between the light source and the condenser. The same thing is true for the incandescent lamp. If it is desirable to go to higher wattage and higher brilliancy in the light source more space is required from the light source to the condenser. All of these features have to be considered in the ultimate result obtained on the screen and, even though there is a greater percentage loss of the light obtained from a high power

light source than from a low power one, still it is possible to get a more desirable result with the more wasteful system.

There has been considerable discussion and difference of opinion in regard to the efficiencies and desirable results obtained with different condenser system which may be classed broadly as the plano-convex system and the corrugated system, and I believe there are still very decided differences of opinion as to what is actually obtained on the screen. I think that most of the tests have been made with an open aperture plate and no shutter on the machine, or at least the shutter open; while the true result we get is through at least a partially diffusing medium in the aperture plate with the shutter rotating. Until all these factors are taken into consideration a proper solution to the problem will not be obtained.

Mr. Ott: It seems that there is one rather important factor left out of the discussion. The object of any condensing system, of course, is to give light on the screen, but the object of the motion picture machine is to give an image on the screen, and this brings up the point of the large projection lenses versus small projection lenses. Certainly you can get more light through a large projection lens, but the point in question is how much good that light does you in the actual image on the screen. The aperture being increased for the same focus means that you are going to get a considerably larger diffusion circle for any point object, in other words, for the image, you get, instead of a point, a dot with a ring of diffusion around it, and a considerable portion of the actual light that starts out from the point source is taken up by this diffusion ring. It simply means that the matter of condensers really should take this into account, because, whereas, if you double the aperture, you theoretically increase the light four times on the screen but you actually do not get anywhere near four times the amount of psychological effect, as it were, to the observer of the picture. Really it seems to me that the best possible condensing system would be one which takes in a very large angle of light from the source and which would allow the use of a rather small or low aperture ratio of projection lens. You get an increase of snap and brilliancy on the screen, whether you get a larger light flux on the screen or not.

Mr. Cook: Briefly, by way of summarizing what we have heard of the theoretical: It seems to me that the practical result that we derive from this is that there is no such thing as an ideal condensing system, illuminating system, or projection lens system, or shutter system, but that it is a matter of compromise and blending of the different elements to accomplish the specific object that we have in mind. Now, it is quite evident that in the theatrical projection the practical necessity is for a maximum size picture of maximum brilliance and clearness, and any mechanism is justified for size, expense, weight, or anything else, which will accomplish that specific purpose. If the traveling salesman wants a machine with which he can project, we will say, the same picture under different conditions, with a small audience and a moderate sized room, then the mechanical conditions become entirely different and he is limited

by the size, the weight and the complexity of the equipment which he can carry.

Now, we have learned, if I am not mistaken, something this afternoon that we were not aware of before, and that is that the small condenser system is capable of giving about 50 per cent more efficiency from a definite light source than the large condenser system. On the other hand, we are told that the limitations of the small condenser system are those of extended size of source, again correlating with the necessary diameter of the bulb which can carry that source without destruction. It seems to me that in every instance the engineer has the problem before him of deciding the proper relation between the size and amount of his light source, the size of his condenser, the size of his projection lens, and the size and position of his shutter. It does not do any good to get more light through a larger projectin lens, if your spot from that projection lens on your shutter is so large that you have got to sacrifice a considerable proportion of it by an increase in the width of the travel blade of your shutter. It is entirely a matter of practical compromise, just as it is in almost any other line of human endeavor. You may shorten the life of your lamp and increase its efficiency or vice versa, but there is no ideal system of the optical train which is adaptable to all the conditions that arise. There must necessarily be an appropriate design of the instrument for the specific purpose to accomplished.

Dr. Story: Of course no projection lens is perfectly corrected over its entire area. A particular zone—a latitude, so to speak—is calculated to give minimum aberation, and the zones inside and outside of this will be less perfectly corrected. The larger the diameter of the lens, other things being equal, the greater will be these imperfections. If the condenser delivers most of its light to the outer zone of a lens having its corrected zone near the center, it is obvious that the image on the screen will not be as sharp as if the majority of the light had passed thru the more perfectly corrected middle zone. Another lens may be corrected for minimum aberation in an outer zone, so that the light delivered to the center does not produce as sharp an image as that thru the edges. Since an appreciable quantity of light cannot pass thru an infinitely narrow zone, there will always be a compromise between illumination and sharpness. Since the area of narrow zones of equal width is proportional to their diameters, if the condenser and source are large enough to fill the whole lens, we get better definition if the lens is corrected for an outer zone rather than for the central portion, since the greater part of the light passes thru these outer regions.

Optical Glass

By H. N. Ott.

THE earliest lenses—those made by Galileo and men of his time were made of glass, not optical glass in particular, but any glass; —the glass available. In other words, in early times there was no such thing as optical glass as we now understand the term. As time went on and the demand for better lenses and a greater variety of the same increased, greater attention and more careful calculations were brought into play. It became evident, as was demonstrated by Dr. Abbe in the early 80's, that the then existing varieties of glass were not sufficient either in quality or diversified properties to meet the needs. About this time both in France and Germany some real research was begun in the manufacture of optical glass as we now know it. Problems not only in making a greater variety of glasses but in eliminating defects in the kinds already made were pressing for solution. Indeed, some of these problems are only recently being solved. This is particularly true in regard to annealing, for we find that our own glass is much better annealed than that of foreign makers who have been working at the problem for years. We have given considerable attention to the annealing and have adopted some really scientific methods which have brought very satisfactory results.

Fig. 1—Mixing the Glass "Batch"

For the past forty years the German, French and English makers have been working to perfect the different optical glasses and have met with a marked degree of success;—so successful have they been that before the war it hardly seemed necessary or advisable for the American manufacturers to interest themselves. At least, they followed the lines of least resistance and as a result no optical glass of

any account was made in America before the war. The exception to the rule are some few pieces of really creditable optical glass made by the Macbeth-Evans Co., under the special patronage of Mr. Macbeth with the aid of a Frenchman who had had some considerable experience in France. This was in '93. Samples were exhibited at the Chicago exposition that year. The attempt was given up on account of the unreliability of the Frenchman and the lack of any encouragement from a commercial point of view.

In 1912 the Bausch & Lomb Optical Co. began experimenting, having secured the services of a very able Belgian by the name of Martin, who had some formulae handed down to him by his father. They succeeded in making some very creditable glass, considering the rule-of-thumb methods used, and the constant fear of exposing cherished and secret formulae. They worked along in this way until we went into the war, when they were given aid from the Geophysical Laboratory of the Carnegie Institution.

In 1915 the Bureau of Standards took up the problem in their laboratory in Pittsburgh. In two or more years experimenting they made some creditable glass, but their greatest contribution to the war needs was their work which produced suitable glass pots.

Right here credit must be given to Mr. Karl Keuffel of the firm of Keuffel & Esser, for producing some very good glass, also for successfully making pots suited to his purpose.

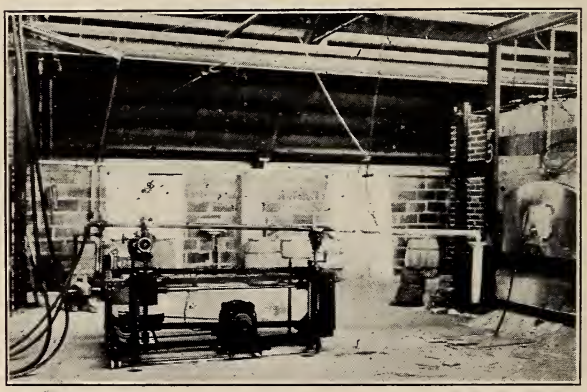

Fig. 2—The Stirring Machine

Mr. Duval of the Hazel-Atlas Glass Co., of Washington, Pa., working in conjunction with the John A. Brashear Co., succeeded in making a small amount of optical glass which was used by the latter mentioned company.

In 1915 The Pittsburgh Plate Glass Co., at their Charleroi plant, began some experimenting, looking to making both spectacle glass and the other higher grade glass used in lenses of greater precision. With the former they met with considerable success but with the latter they worked along contending with varying vicissitudes and

meeting with questionable success until the members of the Geophysical Laboratory took over the management of their plant early in 1918. With these men in charge they made some useable optical glass, but it was not up to the standard desired because of several defects, chief among which were the old furnaces, which were not provided with regenerating chambers and the proper temperature control was impossible.

This brings us to the efforts of the Spencer Lens Company. Within two month after the outbreak of the war I went to England to pick up what optical glass I could which would be suitable to our needs. I succeeded in geting a little and came back thoroughly convinced that we must make our own glasss. In the summer of 1915 we built one small furnace in our factory at Buffalo. We tried several different glass makers who were experienced more or less in ordinary glass making, but all to no avail. Pot after pot, each after a period of about two weeks consumed in slowly heating up the pot in the furnace, making the glass, and then slowly cooling down furnace and glass, proved to be worthless.

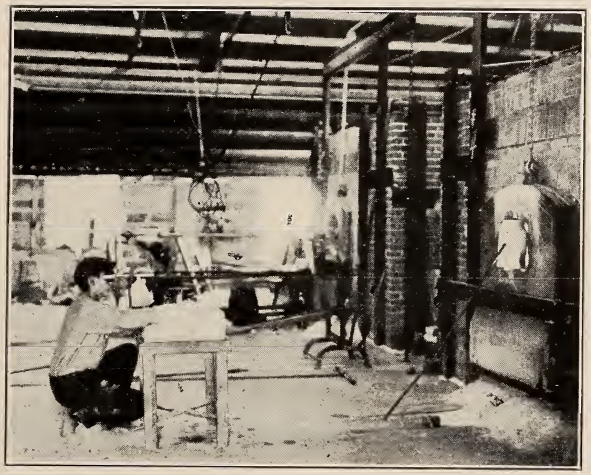

Fig. 3—Taking the Temperature of the Furnace

In the Spring of 1916 we secured the services of Mr. Martin, a brother of the man working with the Bausch & Lomb Optical Co. He soon convinced us that he was a man of much greater ability in this line than any we had had. After a number of experiments he convinced us also that optical glass was impossible with the equipment then in use.

We then bought land in Hamburg—a suburb of Buffalo—where we could get an unlimited supply of natural gas. By March, 1917, we had a modest plant running there with regenerator furnaces with which we turned out a small amount of useable optical glass. We encountered great difficulties even with the better equipment.

We did improve both in quantity and quality, but not until we were given help from the Geophysical Laboratory did we really begin to make optical glass successfully.

Right here I take pleasure in quoting from a paper,* "Optical Glass and Its Future as an American Industry," written by Dr. Arthur L. Day, who was in charge of Optical Glass Production, War Industries Board.

"In contrast to this situation, and to the difficulties encountered at Charleroi, it is interesting to consider the progress of the small plant of the Spencer Lens Company, at Buffalo, in the same interval. This plant was new and though small was capable of competent control. Accordingly, production up to the existing capacity began in the month of December and continued uninterruptedly thereafter until June, 1918, when it was approximately doubled by additional building, and in August, when it was doubled again. Two of the members of the staff of the Geophysical Laboratory (Drs. Fenner and Bowen) went from the Rochester plant to start this furnace, and of the first 22 pots which were put through after their arrival not one failed."

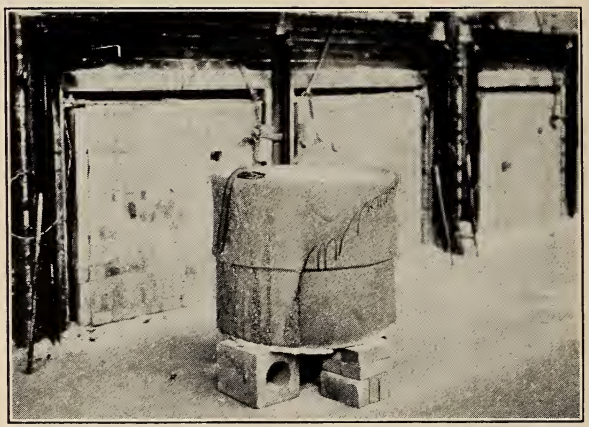

Fig. 4—A pot which has just been taken from the furnace—Ready to go into the Pot Arch to cool.

This tells the story better than I can. We progressed rapidly in quality and quantity. I am glad to say that before the armistice we were making glass which was selected for *some of the most particular optical work* at hand. Since the armistice we have kept steadily at it, improving our quality and increasing the number of different glasses made. In spite of the fact that the war demand was cut off we have thus far been able to keep moderately busy. Since trade has been opened with Europe, however, their glass has been coming in at such low prices that I do not know how much we will be able to make, other than that which we use ourselves, if we do not get a proper protective duty. It would be a shame if an industry so successfully built up under such adverse circumstances, and so vital to

* Journal of the Franklin Institute, 1920, p. 453.

the best interests of the country in general, should be allowed to languish because of no protection from the cheaper foreign labor. We hope to get this protection in the tariff bill now before Congress.

In its essential constituents optical glass is no different from any ordinary glass. All glasses are silicates of soda or potash combined with lime or lead. Baryta and magnesia are sometimes involved. The difference is largely in the physical and mechanical treatment of the glass in the making and the proper balancing of the constituents rather than in the constituents themselves. The careful selection of the clays entering into the pots is a vital consideration. Absolute purity of the chemicals used and sand free from iron are also absolutely necessary. The "batch" consisting of the sand and other ingredients entering into the glass is thoroughly mixed with wooden shovels in large wooden mixing vats. It is then taken to the furnace and little by little poured into the pot through a small door in the large door of the furnace. The pot in the furnace has been previously slowly brought to proper heat for the furnace in a pot arch. With most makers the pot is in the furnace at least 48 hours during the filling in of the batch and stirring of the glass. We are doing it very successfully in 24 hours. This has its advantages, not only in economy of fuel, but in less likelihood of contamination from the pot. The alumina and other impurities from the pot are likely to form striae which are fatal to optical glass. The sooner the melting process is completed the better.

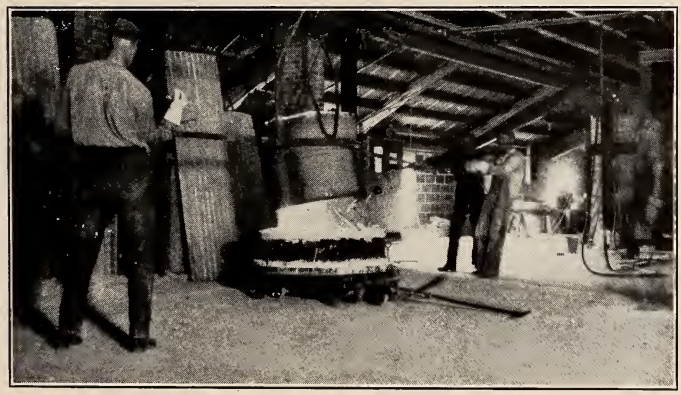

Fig. 5—Pouring a pot of glass to make a large disc.

During the latter part of the melting process the glass is thoroughly stirred, the stirring being more vigorous while the glass is hottest,—in its most liquid state. The stirring is gradually slowed down as the glass cools until the glass has become so viscous that the stirrer can scarcely move. The stirrer is then brought to the side of the pot and the pot removed from the furnace to a heated pot arch to gradually cool during four or five days.

When cool, the pot of solid glass is taken from the arch, the

walls of the pot broken away from the glass and the glass, which is usually in several large pieces and a larger number of smaller pieces, is taken to the inspection room for first inspection. Here, if desirable, the larger pieces are broken up to the proper size and each piece thoroughly inspected for imperfections, principally for striae. The imperfect glass is broken away from the apparently perfect glass, and is either thrown away or remelted, depending on its quality. From each pot a small sample is taken and sent to the Buffalo plant, where it is ground and polished as a 60 deg. prism. These prisms are examined by the spectrometer to determine the optical constants of each pot. A careful record of the same is kept. The good glass is taken to the grinding room, where all the sharp corners and edges are ground off before the glass is again heated preparatory to moulding it into slabs. Were these sharp edges allowed to remain they would heat more rapidly than the rest of the chunk of glass and the uneven expansion would cause small checks to run down into the volume of the chunk which might in remoulding show up as an imperfection in the center of the slab. The glass thus prepared is slowly brought up to a heat sufficient to make it plastic. It is then moulded into slabs of varying sizes depending upon the size of the chunks. They are moulded to this form so that the opposite edges may be ground and polished for a more critical inspection.

Fig. 6—The disc—Ready to go into the Electric Annealing Furnace.

The polishing is done after the slabs have been carefully annealed by a slow cooling process for several days. The slabs are then carefully examined through the polished parallel edges for any striae which may have been overlooked in the first inspection and for any other flaws or imperfections. They are also examined polariscopically for any strain due to insufficient annealing. If strain appears it can be removed by reheating the glass and again carefully and gradually cooling it. The other imperfections are removed only by breaking the slab and breaking out the undesirable parts.

The glass is then ready for the market. Each shipment is accompanied by a record of the constants as determined when the pot was broken up. We can mould these slabs to any desired thickness or size. We mould them to different shapes such as prisms, and discs for lenses, some discs being moulded to approximately the curves of the finished lens. The smaller lenses are made from pieces broken or cut from the slabs after they are thoroughly inspected. Slabs of appropriate size are prepared for the larger lens blanks. Indeed, for the very large lens blanks for refracting telescopes the process begins with the cooling of the pot. We try to cool it so as to get one large mass of glass (an "onion") of sufficient volume to make the desired lens disc after all imperfections have been removed. This large mass, or "onion," is treated as before described to bring it to a rectangular mass with polished edges so that it may be thoroughly inspected. Imperfections are likely to show up. If they are located where they cannot be removed without sacrificing too much of the volume the piece is abandoned so far as the large disc is concerned. If the imperfections are toward the edges they are removed and possibly the mass is again moulded to rectangular form for further inspection and removal of flaws. It is finally moulded to the form of a disc of the desired diameter and thickness. You will notice that I stated that this disc is for a refractor.

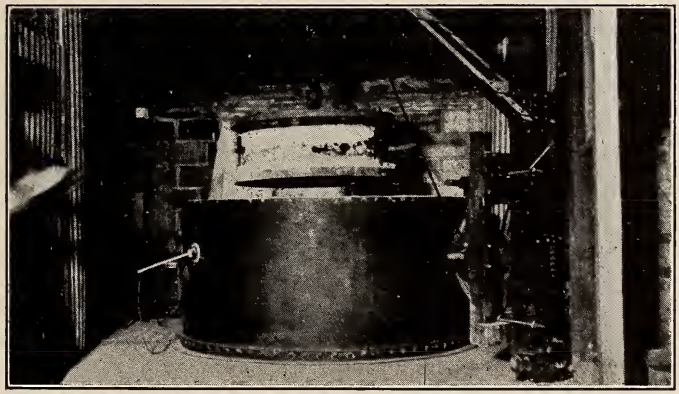

Fig. 7—The disc going into the Electric Annealing Furnace.

For a reflecting telescope the process is not so difficult, for here we deal only with the surface of the glass in the form of a mirror silvered on the concave surface. The quality of the glass in the mass is not important so long as an even surface is obtained.

Such discs are larger than the others and are poured directly into the mould from the pot. The mould, which is lined with fire brick, has a heavy cast iron top and bottom which are bolted together after the mass of glass has been poured into the mould. The mould containing the glass is then put into a large electric annealing furnace and held at a constant temperature—of about 450 deg. C.—

for about fourteen days. By means of an automatic electric control, the temperature is then allowed to fall at the rate of .2 deg. C. per hour for four days, then .4 deg. C. per hour for a like time. The cooling rate is gradually increased as the glass cools until it is ready to be removed from the furnace. It can then be cooled somewhat faster until the disc is cool enough to come out. The whole cooling process requires six weeks for a large disc. We are just now completing the process on a disc 40 inches in diameter, the largest disc, by far, ever made in this country. Very few larger ones have ever been made.

In speaking of the large discs for the refractors, I should have stated that the same care in annealing is required whenever the mass is reheated and remoulded.

I was asked to say something about the making of lenses, but I have already taken too much time. Lenses are another story we will reserve for some other time.

Discussion

Dr. Kellner: I have hardly anything to add to Mr. Ott's comprehensive description of glass making.

We had at the Bausch and Lomb Glass Plant experiences very similar to those of the Spencer Lens Company; the principal difference lies simply in the volume of production.

Our first efforts date back to the year of 1912. Our progress was at first slow and our production somewhat wasteful, but when this country went into the war we had so far advanced that for the 8 months previous to April, 1917, we were able to use glass of our own make for practically all our products. Our consumption of optical glass was then about 20 tons per year. Later on the requirements became very much greater and it was at this time that the wholesome influence of the Geophysical Laboratory's cooperation made itself felt.

To give an idea of the quantities involved, I cite just one example: one of our main objects in quantity production was the making of field glasses for military purposes, which reached the figures of 3,500 pair per week. Each of these glasses contains four right angle prisms of about 44 mm. length and 19 mm. width at the base. The prisms for the field glasses produced during the first 10 months of the year of 1918, when packed together tightly would form 6 cubes of glass of one meter side of a total weight of 18 tons. If we figure a yield of 25 per cent. out of each pot, the melting of 72 tons of glass was necessary to satisfy this demand, which after all was only a fraction of the total requirement. Altogether we produced about 65 per cent. of the glass used for military instruments during the war.

Glass for spectacle lenses, which Mr. Ott mentioned, is treated differently. Here the contents of the pot are dumped on a large flat iron table and rolled out by a heavy iron roller. The flattened sheet of glass is pushed into an annealer and afterwards broken up into pieces of suitable size.

Mr. Ott: Mr. Chairman, I have forgotten one thing which I think perhaps these gentlemen would be as much interested in as any one thing—in regard to the optical glass. It is just in the experimental stage, and what we have done has been only done in our small experimental laboratory furnaces. We have been working on heat-absorbing glass. There has been a demand, as you all know, for glass absorbing the heat, so as not to burn the film, especially when the film is started. In school so often a student comes up with his hand and he wants to see that picture a little longer. Of course, no such thing occurs in commercial use or in the theaters, as there is no demand for thus stopping the film.

We worked for some time with the Corning heat-absorbing glass, but we couldn't get anything that would stand the heat. It would absorb the heat all right, as we know, but it would break. We have been experimenting to get heat absorbing glass that would absorb heat and at the same time stand the racket. We made several tries with glass, one of which broke and one of which did not break; it was fine, but it did not absorb the heat. We have been experimenting with a Graphoscope—I think you have heard of the Graphoscope—we have a piece of glass now with us we succeeded in leaving in 12 minutes; I don't know how much longer it will stand. It absorbs what percentage of the heat, Lloyd?

Mr. L. Roos: In the neighborhood of 187 degrees Fahrenheit. The last three molds have been very successful and have stood up any length of time you chose to leave them in the machine.

Mr. Ott: What was the percentage of light absorption?

Mr. Roos: About 10 per cent.—a trifle over 10 per cent.

Dr. Kellner: About what thickness?

Mr. Roos: Four millimeters.

Mr. Ott: It is not good business to announce that, gentlemen —from a purely business standpoint to announce anything that is kind of half-baked; in fact, it is only half-baked. I am not a business man now; I am here in a scientific crowd, and I announce it because I think you are interested in it. Whether or not it succeeds, and whether we can make it right;—so that we can make them so that nine out of ten pieces will stand the racket, I don't know but we are working along that line.

Mr. Roos: Lest I be mistaken on this ten per cent. proposition, I do not mean that the glass absorbs only ten per cent. of the illumination, but after the machine is stopped the illumination is about ten per cent. less than when the shutter is running; which means that the transmission is about 40 per cent.

A Point Light Source for Laboratory Use

By C. A. B. Halvorson, Jr., and S. C. Rogers

THE term "Point Light Source" is frequently made use of in the calculation and discussion of optical matters. It should always be kept in mind, however, that such a source is only hypothetical and represents a theoretical limit that is unattainable by any means whatever. In a quite similar manner, textbooks on optics give explanations and even formulae for calculating lenses on the basis of a lens with infinitesimal or zero thickness. These theoretical concepts are, of course, of considerable value in working out an optical system, and their use for such purposes should not be decried. In fact, some such assumptions are almost a necessity for the practical development of applied optics, but the fact remains that they are only hypothetical assumptions which can never be realized, and allowance must always be made for the finite or actual dimensions of the real physical light source. The astronomical telescope may perhaps be an exception, for the fixed stars as seen from the earth are point light sources for all but the most extremely delicate apparatus. In the observation of stars, however, another difficulty is encountered, i. e., the image of the star is not a point but has quite appreciable dimensions due to diffraction.

Assuming that a point light source were possible of attainment and available for laboratory or commercial use, it might be of some interest to consider its optical properties. In the first place, its dimensions would be infinitesimal and only a single ray of light could proceed from it in any one direction. Then again, its intrinsic brilliancy would be infinite—a conception more impossible to comprehend than its infinitesimal dimensions. The significance of this intrinsic brilliancy must be further considered. We are accustomed to calculate intensities in an optical system which bear a definite relation to the brilliancy of the light source. If now these brilliancies were infinite, there would be no limits to the possible attainable illumination. On the other hand, the fact of its infinitesimal dimensions demands an almost infinite accuracy in all parts of the optical system. In order to produce a uniformly lighted area of any physical size whatsoever, a curvature of lens or reflector that is absolutely perfect would be required, which in its turn also is impossible of attainment.

With a point source of light, there would be but one ray in a particular direction and no parallel rays since all rays would diverge. This would mean that all shadows cast by an opaque object would have perfect definition. A picture from a lantern slide, for example, could be projected without any lens or other auxiliary apparatus and a perfectly clear cut view be obtained.

Since the above hypothetical point source of light is impossible of attainment, it may be of interest to see the nearest approach to a

point source of light that has thus far been constructed and is proving to be of practical use in the laboratory (Fig. 1). The filament

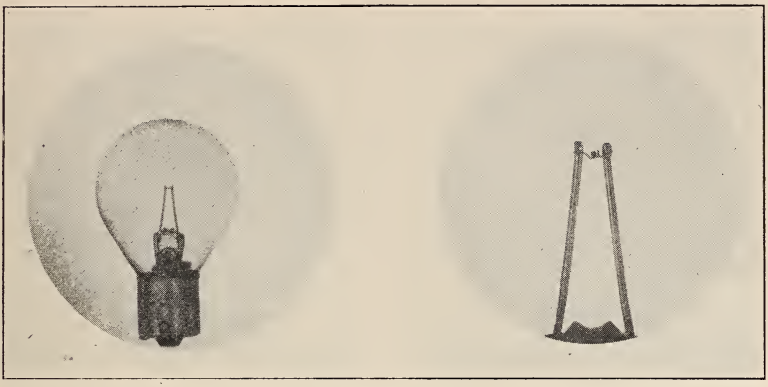

Fig. 1—The nearest approach to a point source of light that has thus far been constructed.

coil is less than .2 millemeter in diameter and .4 millemeter long and is mounted in an S-11 tipless bulb. By placing this practical small size light source back of a lantern slide, it can be shown that this source of light approaches the theoretical considerations stated above. Fig. 2 shows the definition obtainable from this light source. When the distance of the light source to lantern slide is known the size of the picture can easily be determined mathematically for any distance of the screen from the slide. If a larger picture is desired it can be obtained in two ways:

1. By moving the screen further away from the slide, keeping the distance of light source to slide the same (Fig. 2).

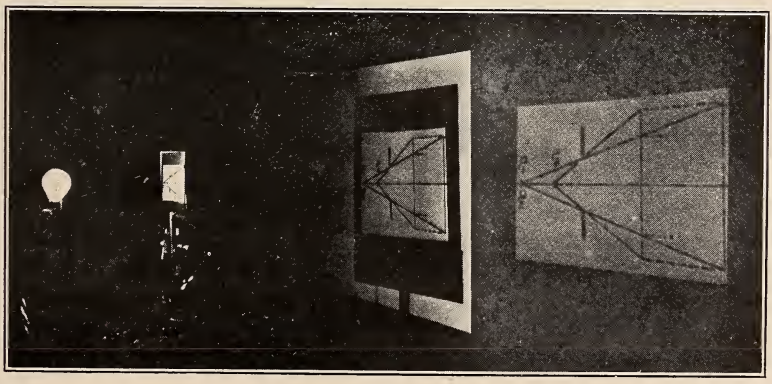

Figure 2

2. By moving the light source nearer to the slide, keeping the distance of slide to screen the same (Fig. 3).

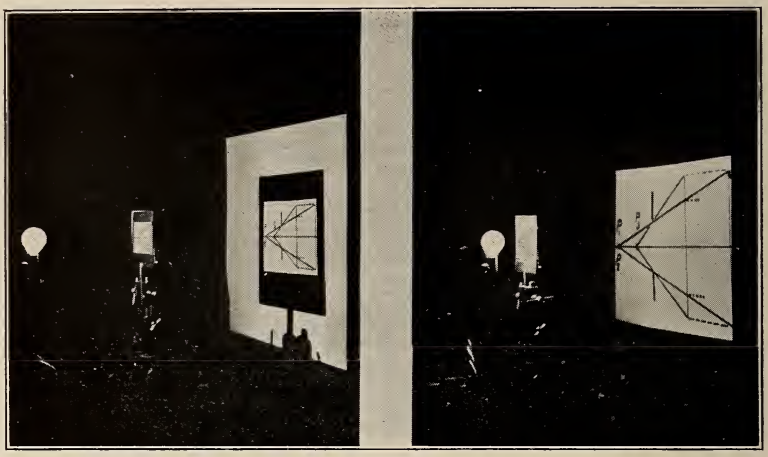

Figure 3

This is shown diagramatically in Fig. 4, where P_1, P_2 and P_3 are the locations of the light source, S_1, S_2 and S_3 the distances of the light sources from the slide D_1, D_2 and D_3, the distances of slide to screens H_1, H_2, H_3, the respective heights of the pictures and a_1, a_2 and a_3 the angles subtended by the slide.

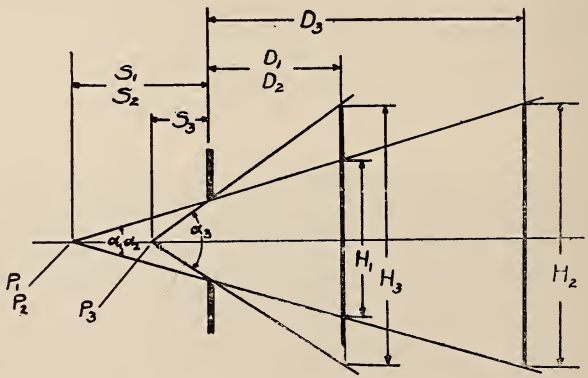

Fig. 4—Diagram showing the two methods of obtaining a larger picture.

When the first method is used the average illumination of the same size picture will be less than by the second method, since the subtended angle is constant and distance to the screen increases in the first case and the distance to the screen is constant and the subtended angle greater in the second case. (Fig. 5).

On the other hand, however, better definition should be obtained by the first method since the farther away the light source from the slide the nearer it approaches the hypothetical point source of light condition. (Fig. 5).

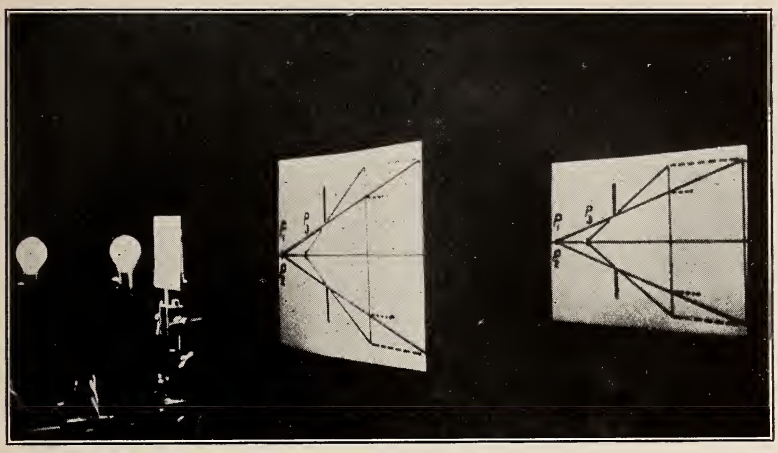

Figure 5

When this lamp is operating at its normal rated capacity the temperature of the filament is approximately 2800° C. and its intrinsic brilliancy approximately 10-12 c. p. per sq. mm. If now this be operated beyond its rating, the intrinsic brilliancy will increase enormously until burn out occurs through melting of the filament. When this condition is reached, the temperature is approximately 3300° C. with an intrinsic brilliancy of approximately 70-75 c. p. per sq. m.m. or an increase of six to seven times. In order to equal in size of picture and light intensity the picture obtained from the commercial 30-ampere 900-watt Mazda Motion Picture Projector Lamp operating with the customary commercial optical system, an intrinsic brilliancy of 10,000 c. p. per sq. mm. would probably be required, since it is doubtful whether an angle greater than 90° could be subtended by a film and still have any definition at the edges on account of its plant instead of spherical surface. This intrinsic brilliancy of 10,000 c. p. per sq. mm., which is sixty to seventy times that of he ordinary carbon arc, woud mean a temperature of approximately 10,700° C., which would be far above the melting point of any known substance and thus be impossible of attainment. From the above it is evident that the total light flux or lumens of the lamp plays a very important part in light projection.

Suppose, however, a larger light source be used, so that advantage may be taken of its larger area, what will happen then? The definition or sharpness of the picture will blur (Fig. 6), the amount

of blurring depending upon the size of the source and its distance from the slide. The greater the latter distance the better the definition will be, but the intensity of illumination will be weaker.

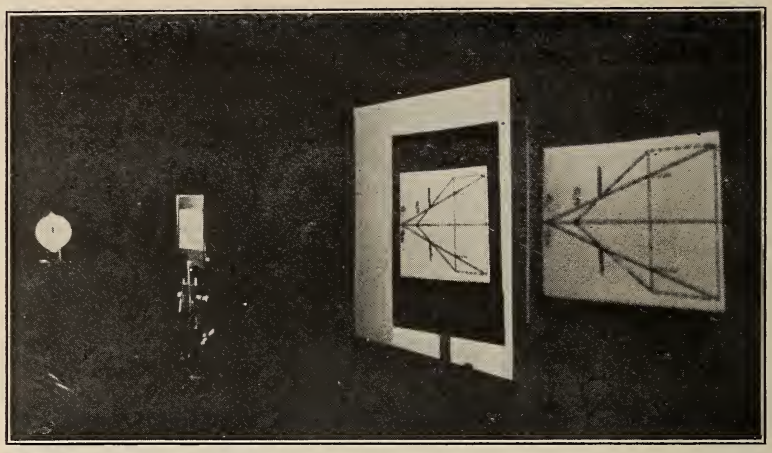

Figure 6

Thus far only projection has been considered that utilizes no auxiliary apparatus such as reflectors or condensing lenses, projection lenses, etc.

If used under any of these conditions, the intrinsic brilliancy and temperature of the filament would have to be greatly increased, due to the inefficiency of present optical apparatus, etc., and since the values already given are unattainable, it is useless to speculate as to what these values would have to be.

It might be of interest to make a comparison of the 4-ampere 50-volt Mazda C Projector Lamp (filament area 7 m.m. square) and the 30-ampere 30-volt Mazda C Motion Picture Projector Lamp (filament area .4 inch x .4 inch, the largest size source used commercially at present) the first being used with a small diameter condensing system. In order for the 4-ampere 50-volt Mazda Lamp to equal in size and intensity of illumination the picture obtained with the 30-volt Mazda C Lamp, its intrinsic brilliancy would have to be approximately 3000 c.p. per sq. mm. and its temperature approximately 7000° C, another unattainable condition. On the other hand, the total light flux would only have to be three times its present output. It should be borne in mind, however, that of the two lamps above mentioned the former is operating normally at a much higher efficiency than the latter, and were the latter lamp to operate normally at a higher efficiency, the values just given would have to be greatly increased in order to equal the resultant increased screen illumination.

A novel means for studying the path of light through an opti-

cal system using this light source has been developed (Fig. 7)

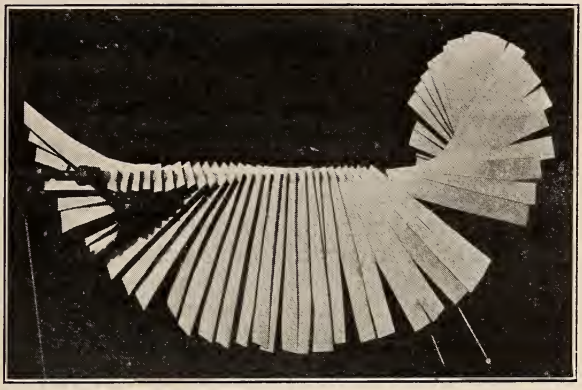

Fig. 7—A novel means for studying the path of light through an Optical System.

which has a decided advantage over the old smoke box arrangement in that the third dimension of the beam can also be viewed (Fig. 8)

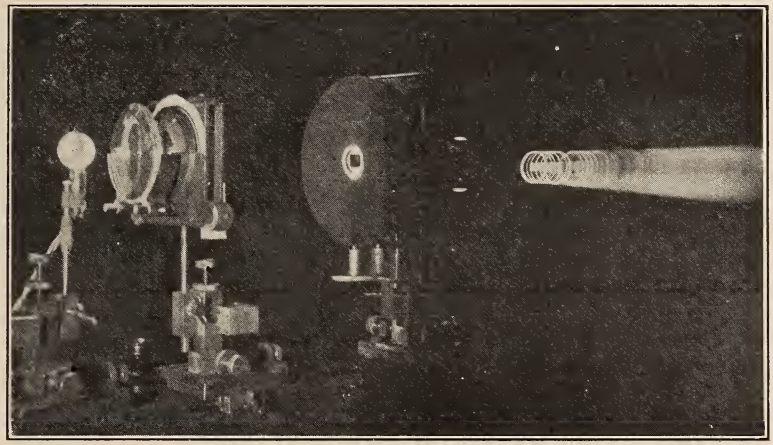

Fig. 8—The Third Dimension of the beam can be viewed with this arrangement.

and diffusion of light from the smoke is absent. Demonstrations can be made showing the path of light through various condenser combinations, reflectors, objective lenses, etc., for different set-ups and alignments of the optical system, all of which are very interesting.

Discussion

Dr. H. P. Gage: In view of the physical difficulty always encountered in bringing a nice piece of apparatus like this to demonstrate before the society, I believe we should be very grateful to Mr. Rogers to this very interesting demonstration which he has brought before us. As to the conclusions, I think we have seen what Mr. Rogers has been demonstrating, and we should certainly be very grateful for his effort in bringing this demonstration to us.

Dr. Mott: I think in regard to this point source of light, if I may digress for a moment, there are a great many lines along which expansion towards higher intrinsic brilliancies are possible under laboratory conditions. I don't think that all of them are industrially practical, but it may be worth while to suggest three of them.

The first method of getting higher brightness and temperature than that of the pure carbon arc is by increasing the atmospheric pressure to 22 atmospheres, under which condition the intrinsic brightness will be increased 18-fold, as shown by the experiments of Lummer.

The second method consists in using materials that have a higher boiling point than carbon. Of these, tantalum gives a greater brightness, three to five times that of the pure carbon arc, because its boiling point is about 5,500 degrees Centigrade, whereas the temperature of the pure carbon arc is about 4,200 degrees Centigrade.

The third method of getting a temperature higher than that of the pure carbon arc consists in using a very high energy-density on good light-emitting vapors in the crater cup of a high intensity positive. This last method has been reduced to considerable commercial success, as you all know.

There may be other methods of approximating a point source of light of very great intrinsic brilliancy. The high intensity arc will give an intrinsic brightness three to ten times that attainable with the ordinary carbon arc. Now, there may be several methods of securing very high temperatures, and the combination of two or more of these three methods would be feasible from a laboratory standpoint and would produce tremendous intrinsic brilliancy.

Industrial Mechanigraphs

By Harry Levey.

YEARS ago, when motion pictures had just emerged from the experimental stage and were wholly novel as a means of entertaining the pleasure-seeking public, anything that moved upon the screen was not only considered worth seeing, but worthy of the exclamatory comment that greeted each new wonder. The thing was amazing, and without ocular proof it would be almost incredible. And the mere wonder of the motion picture was quite sufficient, for a while, to make it attractive, regardless of subject or handling. It was enough to see pictures that moved. Why be critical of details?

Today the wonder of the moving picture is wholly forgotten, and hopelessly unsophisticated is he—or she—who cannot pick flaws in productions that only a few short years ago would have been considered flawless. In fact, such productions were impossible to make at that time.

In other words, the public has been educated up to a much higher type of motion picture than that at which it first marveled. And, what is more, it has been educated up to the point of expecting even better—in fact, something better is being *demanded* as a matter of course. And, equally of course, that demand is going to be, and is being, progressively, met.

Of the theatrical type of picture the public, generally speaking, knows a good deal—too much, perhaps, for the peace of mind of the producer whose one aim in life is to keep just one jump ahead of his audiences and who frequently finds his heels entangled with the toes of his fast-growing critics. There is, however, another type of picture that is less well known, but which, it is firmly believed, will shortly find for itself the place in public estimation that it so well merits. That is the type that is best known as the "animated mechanical picture," though it has long outgrown that designation.

As a matter of fact, the animated mechanical picture is a direct descendant of the cartoon. Years ago the untiring search for something that would lend novelty and variety to screen showings led to the development of the now familiar animated comic drawings, and it is unnecessary to call to mind the favor with which they were received when first exhibited. It was not long, however, before the crudeness and the obvious limitations of the plan became more or less conspicuous, and the public demanded something of the same sort, but much better. So today we have what we called cartoons, but which have every appearance of being actual photographs of utter impossibilities—really wonderful productions made by complex and highly ingenious processes. The old ideas, outgrown, paved the way for something better.

The animated mechanical drawing was at first precisely what

the term indicates—a drawing that differed from the ordinary fruit of the drawing board only in that it moved in much the same manner as the machine, or whatever it might be, that was portrayed. This was of course very good indeed, as far as it went, and it supplied something that appealed mightily to many who appreciated the luxury of being taught, in an entertaining way, things that could not otherwise be grasped without more or less distasteful study and application. Later the animated drawings were improved by washing and tinting, just as the ambitious draughtsman of ten washes his exhibition drawings—after which he put them in frames under glass and keeps them for show pieces.

But, just as the original form of cartoon was forced to give way to the modern, life-like type, the animated mechanical drawing has had to give way to something more advanced—the "mechanigraph."

The term "mechanigraph" is the trade name given to motion pictures of animated mechanical and technical drawings and models developed and improved by the organization with which the author is connected. Mechanigraphs differ from other animated technical films rather in the care and thoroughness with which they are made and the knowledge of subject matter and the engineering skill behind them, in the refinement of details of method and equipment and in the artistic character of execution rather than in the basic procedure of machinery of manufacture. It is the purpose of this paper, therefore, not to explain the basic features of mechanigraph production, with which you are already familiar, but only to point out a few of the more conspicuous details of method in which mechanigraphs are different.

OBJECTIVE MATERIAL

Let us consider, first the objective material used under the camera in making mechanigraphs. This consists for the most part of flat working models, supplemented by technical drawings, of the machine, operation, process or idea to be presented. The models are usually made of especially prepared fibre board, drawn, cut out and washed with air brush and by hand so as closely to resemble the real object. One of the secrets of success in mechanigraphs is that where an actual object is presented the picture looks not like an animated drawing of the object but like the actual object itself. Great pains are exerted to attain this result. Even where a series of superimposed animate line drawings would clearly illustrate the lesson to be taught, our mechanigraph engineers are not satisfied, but go to considerable extra trouble to make a picture, say of a metal part, actually to look like metal, of wood to look like wood, and of flowing liquid or gas to look not like symbolic moving dashes but actually like flowing or floating gas. Sometimes it happens that the effect sought in a mechanigraph is not a simulation of the ultimate object itself, as, for example, an automobile, but a representation of, say, the plan or drawing. Recently we prepared a mechanigraph whose purpose was to simulate a drawing of certain features of the car,

and the resultant picture on the screen was, through the instrumentality of an animated line drawing white on black, of strong contrast in the photography, of extreme under printing and of blue toning, a striking simulation of an animated blue print.

To increase similarity to the original as well as to facilitate execution, the actual original objects themselves or parts of them are wherever possible used in the mechanigraph. One of the first mechanigraphs was of a machine which makes hooks and eyes. The model of the machine was made of fibre board but the wire, the hooks and the eyes were the real articles, taken from the actual machines at various stages of manufacture.

As another effort toward true representation, it might be worthy of mention, merely as an example of attention to detail on a rather large scale, that a graduate mechanical engineer, the author of several text books on engineering and who has been technical editor of engineering periodicals, plans and supervises the making of mechanigraphs, while a paint and brush artist, whose only concern in life is to make his pictures true representations, handles the coloring and shading and free handwork. The combination of two such forces comes pretty near to the attainment of an ideal result.

Perhaps it is a little curious that there is very little that is new in the way in which mechanigraphs are made. On the contrary, effects are produced by resorting to all the well-known methods. Of course almost every new job calls for some little ingenuity in treatment, and numerous little schemes have been worked to overcome individual difficulties. But, generally speaking, there is no hard and fast process or method. One job is handled in one way, and another in a different way. The process is bent to the job—not the job to the process. The net result is that there is as much variety in the screened results as there is in the subjects; the subject is not sunk in the process.

CAMERA WORK.

The camera work on mechanigraphs is more often than not done on stop motion, though not exclusively. When a more realistic or graphic result can be obtained through the performance of the objective and photographing it at normal speed or at a speed which makes possible regular cranking of the camera, such is the method employed.

In general, no set methods are employed in producing mechanigraphs. Whatever device or procedure will contribute best to the result desired is used. If actual relief models suit better for a given purpose and will more closely represent the original or more graphically teach the lesson than flat models, if shooting horizontally will result in a better picture than shooting vertically, or if combining straight photography and animation will give better success than using either singly, such is the procedure followed.

SUBJECT MATTER.

The subjects which lend themselves to presentation by mechanigraphs are unlimited. The simplest forms are those demon-

strating the operation of machinery which is either too much hidden and inaccessible or too complex or too rapid or slow or too large or

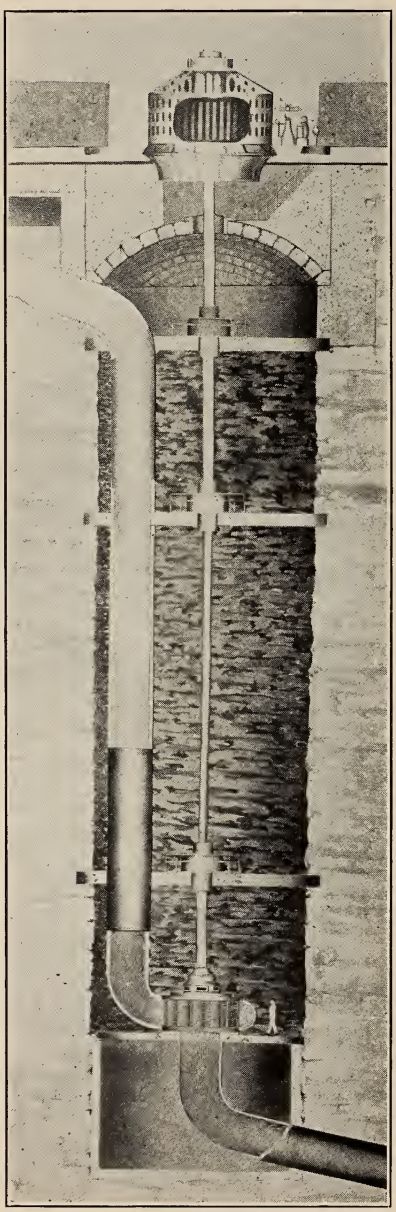

Fig. 1—From Mechanigraph showing operation of Hydro-Electric Turbine Generator at Niagara.

small for picturization by straight photography or which will not operate when opened up to the view of the camera. A recently made mechanigraph showed an entire unit of hydro-electric generation at Niagara Falls (Fig. 1). The power house in which the generators are placed is on a level with the river above the falls, and the turbines which drive the generators are just above the level of the river below the falls—that is, nearly two hundred feet below the generators. Drive is through a long vertical shaft reaching from turbine to generator through a pit cut in the rock, and the penstocks, which carry the water to the turbines, run down through the pits. Obviously it is impossible to actually photograph anything but the power house and its contents. The mechanigraph, however, being blissfully ignorant of such limitations, makes a sharp cut, so to speak, through the rock from top to bottom of the pit and lays bare the whole system. More—it slices off exterior parts that hide inner workings. On the screen the whole unit and all its activites are visible—the water from the canal rushing down the penstock to the turbine, the turbine spinning under the impulse, the long shaft transmitting power to the generator and even the generator armature itself turning in its field. The appearance of the job is true to life, as nearly as it is possible to make it—so true, in fact, that one skeptic asserted, with a shake of his head, that he did not believe it *was* really a photograph, for he did not see how it could be done.

We have succeeded in making water flow on the screen in much the way water appears to flow in reality. That is, the observer sees that a transparent body is in motion, but there are no visible lines or streaks to help his eye to deceive his brain. The flow of gases is shown in the same way, without the use of arrows, dots and dashes or other arbitrary symbols which savor of the drawing board and take away from the appearance of reality. Smoke and steam look like smoke and steam. Clouds and lightning *are* clouds and lightning, and not caricatures. Even the afterglare of a lightning flash glows on the screen.

In electrical work, such as was embodied in a picture showing the principle of the induction motor and its revolving magnetic field, it is of course necessary to assume that electricity looks like something and that magnetism is visible. It is possible, however, to do this and still keep away from an excess of conventionalism, with the result that the screen shows the theory of the motor in a way that appears realistic. This particular picture brings out clearly and understandably principles that are extremely difficult to grasp by the ordinary text-book method.

The same methods are employed in showing the operation of the vacuum gasoline feed system, for instance (Fig. 2). The somewhat complex action of vacuum and atmospheric pressures are clearly brought out, the operation of the valves, the flow of liquid throughout the whole system, and, in fact, every detail. The effect is the same as if the system were split open but still continued to operate.

In a general way, it may be said that the mechanigraph con-

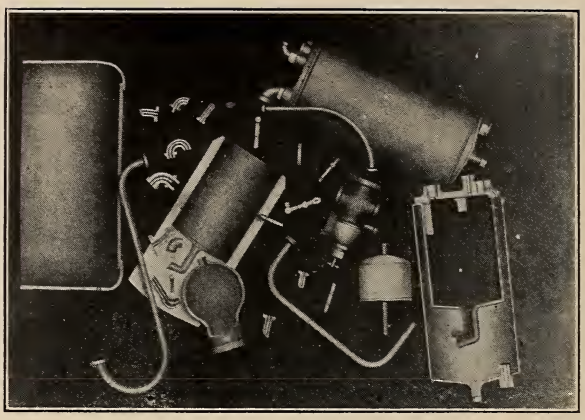

Fig. 2—Broken down parts from Mechanigraph Model of Vacuum Gasoline Feed Mechanism.

sists of a base drawing upon which the moving parts are so mounted as to be capable of their normal movement and action. In the matter of materials, as in methods, there is no set rule. Paper, cardboard, fibre board, sheet metal and other materials are used as occasion may demand. If we can use an actual object to better advantage than a picture of it, we use the object. For instance, in making a mechanigraph of a power-driven tire pump (Fig. 3), we used a thin section of an actual automobile tire instead of making a drawing. The observer does not know where the drawing leaves off and actually begins.

Another unique and novel result attained by the mechanigraph process is the ability to place activities and objects of a mechanical nature in the proper environment and to show them under natural

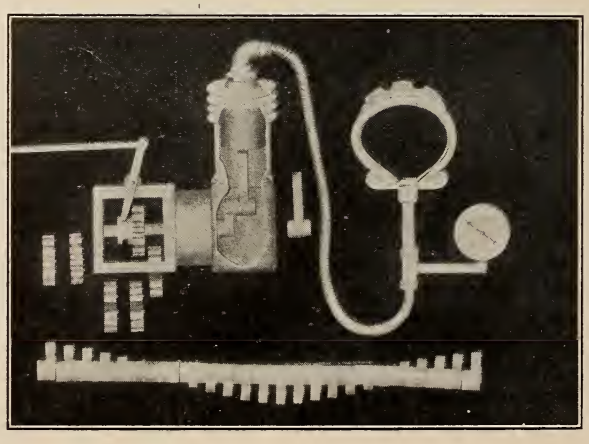

Fig. 3—From Mechanigraph of Motor-driven Tire Pump showing every operation of the Tire Pump in action.

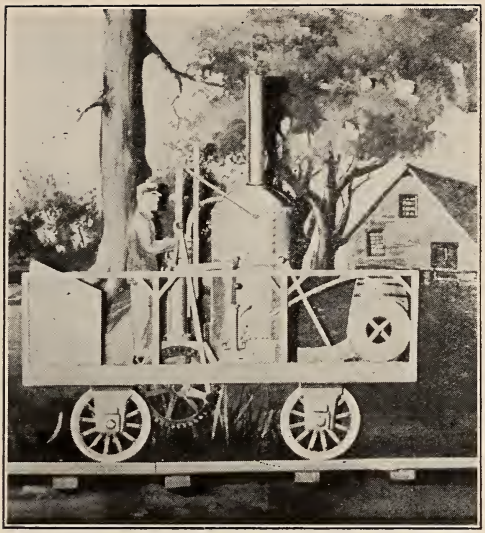

Fig. 4
Mechanigraph of Peter Cooper's First Locomotive

and proper conditions, just as the stage and the photoplay have been able to do in their field. Thus mechanigraph representations of the first steam engine (Figs. 4 and 5) and the early forerunners of the bicycle. (Figs. 6 and 7) show these mechanical inven-

Fig. 5—Representation of the Grass Hopper Steam Carriage, made by means of the Mechanigraph to show the early stag s of self-propelled vehicles in a film history of transportation.

Fig. 6—Mechanigraph reproduction of the Dandy Man Bicycle, the forerunner of the modern bicycle, which appears in motion in "The Porcelain Lamp."

tions not only in actual use but in their proper early nineteenth century landscape setting. And so in the same series, the quaint Dutch wind wagon (Fig. 8) fitted with sails was shown being driven before the wind on the sands of the sea shore, while the first motorcycle (Fig. 9) chugged through the street of a foreign village in the garb of 1880. Thus are combined in the mechanigraph the talents of the scenic artist and the engineer.

Mechanisms far less mechanical are equally well adapted to treatment by mechanigraph. The human body, its parts and the performance of its various functions are as easy to present as machines made of steel and iron.

The mechanigraph is destined to become a most valuable aid in

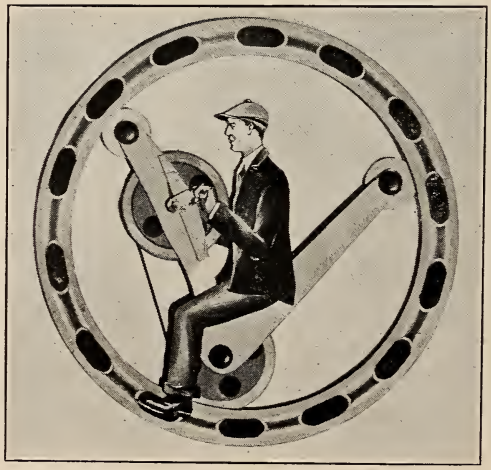

Fig. 7—Mechanigraph of the Unicycle, one of the early forerunners of the bicycle.

Fig. 8—Mechanigraph of wind-driven wagon from "The Porcelain Lamp."

the teaching of medicine, surgery, dentistry and allied sciences, as supplemental to actual photographs of anatomical structures and of surgical and dental operations. No matter how clear and sharp and well done a straight picture may be, many aspects can be more clearly and graphically presented in mechanigraph, and usually what is performed on the operating table or in the dentist's chair is far from open, clear and readily understandable. More often than not the actions and parts to be shown are hidden in other parts, impossible to light and concealed with blood. The mechanigraph is able to make them clear, and easily and accurately followed.

Fig. 9—Mechanigraph of Daimer Motorcycle.

Microscopy will profit immeasurably by mechanigraph treatment. Straight microcinematography is at best only fairly successful in portraying the subject matter. Cross-section mechanigraphs, many times enlarged over the extreme limits of the microcinematograph and many times more graphic and clear, are able to give microscopic subjects and activities a new meaning upon the screen.

Physics, chemistry, mechanics and other phases of mathematics, biology, astronomy and architecture are but a few pedagogical subjects selected at random of the many the teaching of which may be enhanced by this medium.

The mechanigraph process finds its readiest application in commercial and industrial films. Their capacity for the development of microscopic studies, for example, find commercial expression in explaining how paint, which is revealed under enlargement to consist of long fibres holding the substance together, is absorbed into the pores of wood or holds on to the rough surface of what appears to the unaided eye as polished metal, or how bacteria develops in fruit and vegetables canned improperly and how the proper type of jars and rubbers will prevent the development of the destructive germs.

Dull, uninteresting statistics and diagrams, plans and organization and policy charts can be brought to life by mechanigraphs.

Selling and merchandising as well as teaching and general education and entertainment have acquired by mechanigraphs a new, powerful and efficient medium which is as far advanced beyond ordinary cinematography for attaining certain desired results as the ordinary cinematograph is advanced beyond the older methods of the oral or written word.

Analysis of Motion

By C. P. Watson.

OWING to certain tests made in steel foundry production early in 1917 and the inability to obtain more than a momentary viewing of such tests through the medium of standard motion pictures, my thoughts turned to the subject as to how a better understanding of problems confronting us could be obtained, which led to some haphazard, spasmodic experiments along the lines of "slowing down" motion picture photography. During the year 1917 I devoted almost constant study to the subject, and manufactured a crude model of a "Novagraph" camera, in fact, many crude models. I am quite sure were I afforded an opportunity to put a yard-stick on the raw stock used in my experimental work during that single year the gross footage would undoubtedly reach around the world.

Fig. 1—Novagraph "Analysis-of-Motion" Motion Picture Camera. Back and side open. Vacant space, left side, for Duplex Film Magazine Box of 400-foot capacity. Note simplicity of mechanism.

In 1918 I was fortunate in perfecting a "Novagraph" camera capable of producing approximately 125 to 160 pictures per second, which went far to the realization of what I had hoped for.

In the latter part of 1918 and early in 1919 I so far perfected high-speed photography that the product of the cameras then available proved acceptable to the film distributors and met with hearty approval of the theatre-going public.

When "Analysis of Motion" first appeared on the screens of motion picture theatres they caused considerable amusement and very little serious interest on the part of the spectators. They were impressed with the sight of ball players, athletes, swimmers, divers,

horses, racing and hurdling and innumerable other subjects, but utterly failed to appreciate the goal which it was my ambition to reach and in which I foresaw the tremendous, inestimable value of "Analysis-of-Motion" motion pictures.

My ambition had been to prove to the scientific and professional world the value of "Analysis-of-Motion,'" and I may say the "Novagraph" cameras are now being used many times more active in the domain of mechanical and medical science than in the field of pure amusement.

It is not necessary to explain here the great difference between standard motion picture photography and "Analysis-of-Motion" photography. All motion picture people know that if film is exposed to the subject at the rate of four a second and projected at normal speed, action that consumed four seconds in actuality is shown on the screen in one, and the result is the exaggerated speed often used

Fig. 2—Novagraph "Analysis-of-Motion" Motion Picture Camera. Back and side open showing Duplex Film Magazine Box in position, film threaded as in high-speed operation.

in comedies. Pictures taken at the rate of thirty-two a second and projected at normal speed would show in two seconds something that actually took place in one. The new and greatly improved "Novagraph" cameras expose film to the subject a minimum of 480 times per second, and the projection of the positive print at normal speed permits a thirty-second study of an action actually completed in one second.

In analyzing the flight of a 12-inch projectile, weighing 1500 lbs., with a velocity of 2007 feet per second, it was possible to obtain a perfect picture of the projectile as it approached and came in contact with a 12-inch thick armor-plate target, case hardened throughout, through which was proven the projectile did not penetrate the target at the point of impact, as a decided skid was shown prior to penetration. The target was set at an angle of twenty-five degrees

from the gun. Unfortunately, at the instant of penetration flying splinters destroyed the lens and demolished the front of the camera.

Within the past three weeks an "Analysis-of-Motion" picture of an automobile was made, covering 100 feet of measured roadway. The automobile covered the distance in three seconds flat and 1208 perfect pictures in 75 feet of film were secured. In analyzing this test the following results were proven:

1. Four hundred perfect pictures per second were secured.
2. The film exposure was 25-feet per second, an average of 400 feet in 16 seconds.
3. One perfect picture for every inch of the 100 feet covered by the automobile was secured.

In this test the "Novagraph" camera used was by no means driven to its maximum speed. It can readily be operated at double that speed with a possible resulting twice as many pictures per second.

Fig. 3—Novagraph "Analysis-of-Motion" Motion Picture Camera ready for operation. Film exposure 300 per second.

I am proud to say that I have had the privilege of making 'Analysis-of-Motion" motion pictures of many medical subjects, particularly of persons afflicted with nervous disorders resulting in constant and uncontrollable twitching, jumping and thrashing about with arms, legs and body, together with heart analysis pictures, which have won highest commendation both in this country and abroad.

In one instance, as one of ten subjects, I made a series of "Analysis-of-Motion" motion pictures of a young woman, who at the age of seventeen years, lay for many days at the point of death as the result of fright sustained during the course of a particularly severe electric storm. Within two months thereafter symptoms of hysteria developed and continued until at the age of twenty, three years after the occurrence, she became practically helpless, unable to

stand alone, her entire body was in constant motion and her case pronounced incurable. At this point my work started in the hospital in which she was an inmate.

At a gathering of prominent physicians of New York and other cites the projection of the "Analysis-of-Motion" pictures of this particular young woman upon the screen disclosed an hitherto unsuspected muscular agitation in her left leg, which resembled nothing more closely than the quiver of jelly which had been well jellied. This particular muscle tremor extended from below the left knee-cap to the hip, apparently a continuous motion traveling from the knee-cap to hip and returning to its starting point, aroused intense interest in the minds of the physicians, from among whom a committee of three was appointed to examine the subject, with a resulting report they were unable to detect the muscular tremor with the naked eye and that the standard motion-picture film utterly failed to disclose it.

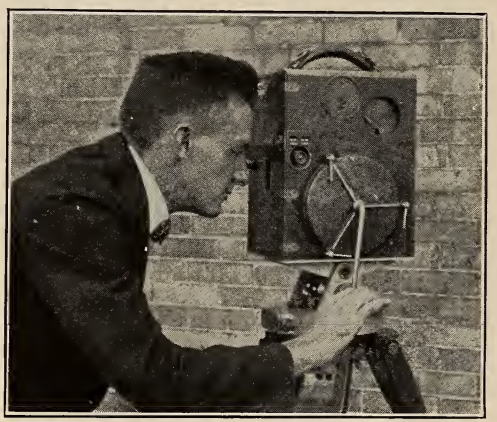

Fig. 4—Novagraph "Analysis-of-Motion" Motion Picture Camera with special attachment increasing film exposure to 600 per second, showing ease of focus at any moment.

Less than a month ago I was informed by a professor of neurology in one of our leading colleges, conversant with the case, that the study of this hitherto unsuspected condition had led to a different course of treatment in connection with nerves leading to the brain, that the young woman had materially improved and it was now safe to say she would ultimately recover.

This muscular movement has been described by the medical profession as a "muscle wave" for the want of a better name.

We should all be proud that motion pictures have risen to greater heights than purely amusement features. They have pointed out a new method of medical treatment which may alleviate the sufferings of humanity and prolong life.

100,000 Pictures per Minute

By C. Francis Jenkins.

THE Papers Committee has suggested that an illustrated talk on what has been accomplished this summer to further the development of high speed photography would be interesting to the members of our Society. It was this suggestion which resulted in the preparation of this paper.

The rate of exposure is 1600 frames per second in most of the pictures which will be shown you, that is, 400 feet of negative is run through the camera in four seconds of time and 16 pictures per foot impressed thereon. The negative is the regular Eastman stock and is not special in any way; the lenses used are the usual B. & L. f-3.5, mounted in a special tube. In the preferred form of camera for extreme speed there is a plurality of these lenses, and they are used wide open all the time. There is no shutter employed. Of course, the only possible way that 400 feet of film can be passed through a camera in four seconds is continuously—intermittent movement being wholly out of the question.

Those who saw the crude results exhibited at the Bureau of Standards' meeting last May will remember that 100,000 pictures per minute was the goal set for the summer's work. Not only has this been accomplished, but results have been attained which are very superior to those then shown, as you will observe from the pictures which will be shown in connection with this paper.

As will readily be suspected, a great many unforeseen difficulties arose as we attempted persistently to make motion pictures a hundred times faster than normal, but these have been overcome one by one until now the camera is set up with a rather high degree of confidence in the result, for the point has been reached in the development of this instrument where a nearer approach to perfection will be made by the skill which comes from repeated use rather than by material change in the camera.

Incidentally I might add that two shots were made at twice the speed, that is, 200 feet of film per second, but on taking out the first roll it was found that the heat generated in the film softened the gelatine to such an extent that the convolutions stuck together and the roll of film could not be unrolled. A second shot was made with the edges of the film lightly lubricated, and very creditable pictures resulted. But as the speed seems to be much higher than there is any call for at the present time, no further work along this line was attempted. However, there does not appear to be any reason for hesitation in undertaking the construction of a camera to handle film at the rate of 3500 exposures per second if need for this should be found; I am quite confident that it can be done.

Surprises continually came up in the work, for one is hardly prepared for some of the phenomena which developed; for ex-

ample, in the first attempt to get more pictures per second than I had therefore made, the heavy spring belt take-up, which had been satisfactory at 50,000 exposure per minute, did not wind up the film at all at 100,000 per minute, for the reason that the belt made a circuit around the pulley it was supposed to drive without touching the pulley at all, centrifugal force holding it entirely clear of the pulley. We put a cord inside the spring belt to kill the force at the end of the tangent and have had no further trouble from that source. At higher rates direct drive and friction plates would doubtless be needed.

Incidentally, new hazards were discovered in attempts to mechanically handle film at 100 feet per second. In first trials some old out-of-date stock was used and the camera door was left open so that the action could be watched. As the last end of the film passed

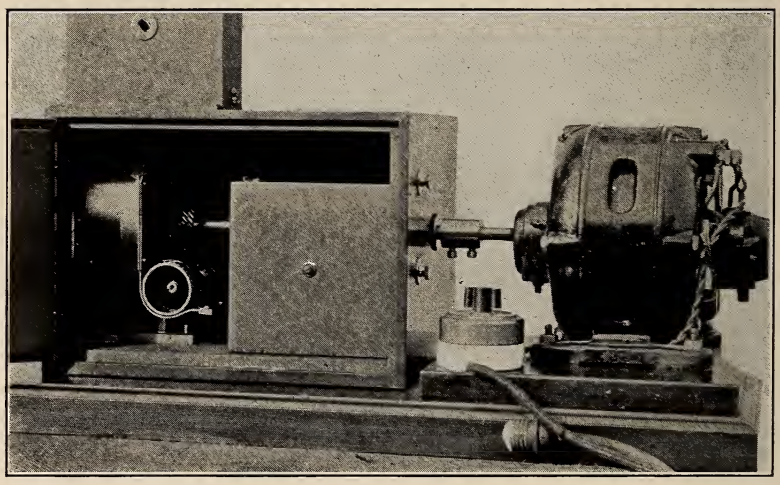

Fig. 1—First model motor-driven camera producing 1,600 exposures per second on Standard Film.

around the sprocket, a piece about 1½ inches long was snapped off and, flying in my direction, cut a severe gash in my bare arm, though I was seventeen feet away. Always there is found in the receiving magazine quite a quantity of bits of film, for the end frays out like the cracker of a whip before the motor can be stopped.

Tension of any kind is out of the question. The best result so far has been attained by guiding the film in a narrow channel made of very dense wood, grainless, and having an oily feel.

Resistance seemed to develop as the cube of the speed. One horse power is required to drive the camera; a ½ horse-power motor will not bring the instrument up to speed. There is but one pair of gears in the camera.

These things are mentioned only to show that very little of past experience in motion picture photography is of much benefit in attempts to handle 100 feet of film per second in a camera.

However, as there are many important problems upon which information can be obtained only by photographic divisions of time at this high rate, all this effort seems well worth while; as for example, information about the recoil of a gun, the flight of a shell, the impact of a shell against plate, is considered by the Ordnance Department very much worth while.

For the Navy, photographs were made of a big HS2 plane getting off the water. The forty-mile-an-hour travel of the plane at the getting-off moment, when reproduced at normal speed, appeared as but one-half mile an hour, and the pilot, when he saw it, seemed realy distressed about this fact.

I have begun, for myself, the use of this instrument in the study of a physical law, not widely known, I believe, but which may be written as follows:

Any object free to move in a fluid will move toward that part of the fluid having the swiftest motion.

This seems to account for phenomena not explained by any other physical law, for example, why strong swimmers are drowned in the ocean undertow, why logs ride the crest of a freshet, why a ball stays up in a stream of air, why plate glass windows break outward, why leaves are lifted off the ground, even heavy boards picked up and carried long distances, why a card can't be blown off the face of a spool by blowing through the hole in the spool, why birds soar the air without apparent effort, why airplanes are sucked up into the sky, (I believe it is not yet very generally known that 75% of the lift of an airplane is above the wing, and only 25% underenath), and why flags flutter.

I was never entirely satisfied with the explanation which you will remember is given in "Alice in Wonderland," that it was her "Old Man of the Mountain" who furnished "utters for flags, rustles for silk dresses, and a very superior quality of post hole."

It seems more logical to remember the law that the body must move toward the swiftest part of the fluid medium in which it rides, and that this force is as increasingly powerful as the difference in the flow in adjacent parts of the fluid stream. My collection of pictures of this phenomena are not complete, and therefore will not be presented at this time.

However, while the samples I shall show you are of simpler kind very interesting phenomena is disclosed even in these, and it is believed valuable data may be obtained by high speed photographic time divisions in science and engineering when taken up seriously, though scarcely a beginning has yet been made.

Incidentally, it may be interesting to note that an entirely satisfactory means for counting the exposures at this high speed has not yet been worked out, and I do not at the moment recall any problem in science or the arts that has required the development of a timing device dividing the second into a thousand or more parts, which is suitable for this work. I would appreciate suggestions.

The timing device we tried and which you will see in the left

hand lower corner of one or more of the pictures, consists of an electric motor so geared to a hand as to give it a hundred revolutions per send over the face of a white dial. The dial is about 14 inches in diameter, and the hand is of thin, light wood made to contrast by painting one end black. Each revolution marks a hundredth of a second, so that the sixteen exposures of each turn are sufficiently well defined for the purpose.

However, as the camera motor itself, making 2100 R.P.M. doubled by stepping up, and multiplied by 24, the lens factor, is fairly reliable, I often find myself counting the exposure for each revolution of the clock dial. In other words, I use the camera to time the timer.

Discussion

Mr. Jenkins: I am very anxious that we do not get off on the wrong foot. I want you distinctly to understand that I am not industrially connected in any way in this high speed research. I am one of these prophets without honor in his own country, perhaps, but somebody always has to go ahead. At a luncheon down in Washington I sat alongside of General Squier, and you remember what a splendid little talk he gave us. Socially, we were talking about the question of invention, and he made a remark which has been in my mind, but undeveloped, as he put it, and that is that somebody has to think of the thing first—somebody has to be the pioneer, whether it happens to be an invention or some particular movement; always any new thing originates first in a single brain. That is why, he explained to me, he had split up his research laboratory into a number of smaller units. He found that he got action faster.

That is my apology, or my excuse, let me say—for coming before you again. I have reached the conviction that engineers in the motion picture business should feel, as I certainly do, that the time has come for us to remove the one limitation which stands in the way of advancement in the motion picture business, and that limitation is the word "intermittent"—and it applies to all sorts of our machines. When you take "intermittent" from our vocabulary, so far as motion pictures are concerned, we can put the picture series on boards, we can put pictures on almost any old thing, because immediately weight and speed are eliminated; that is, weight and speed have no limit practically.

So, please, if you will allow me, that is my excuse for coming to you today. If we can have speed and weight taken out as the limiting factors which stand in the way, I believe that progress can be made faster. When the electric motor came along it would have been just as easy to have made a reciprocating electric motor as a rotary motor, but we would not have made the progress today that we have made. So that is my excuse for standing here and telling you that so far as Mr. Jenkins is concerned, intermittents are taboo from now on.

We have to make a start some time, a beginning, and the way to begin is to commence. Now, if that is so, then any progress, or any demonstration that I may make, simply is in the nature of an invitation to you gentlemen to "come on up." I feel lonesome too far out ahead. Come on up close, and let's tackle the problem together, and as one of the ways of doing it, that is, to show what can be done, I have brought down some high-speed-phenomena-pictures; high speed in the sense that continuous motion has no limit; we can go as far as we like. These I will show you presently.

The Use of Artificial Illuminants in Motion Picture Studios*

By Lloyd A. Jones

A complete treatment of the subject of lighting of motion picture studios requires a consideration of many factors and involves a knowledge of photometry, visual sensitometry, and photographic sensitometry. A large amount of the information necessary for the intelligent use of artificial illumination for photographic purposes is available in the literature, but in many cases this it not commonly known nor is the method of applying this information to practical problems well understood. It seems worth while, therefore, to treat the entire subject in a rather general and complete manner, to outline the fundamental relations between the various factors of the problem, to present some of the available information bearing on various phases of the subject, and to indicate methods of utilizing the available data in practical problems. Such a treatment, it is hoped, will be valuable not only as a summary of our present knowledge of the subject but also as a means of indicating the phases upon which additional experimental work and more complete quantitative data are desirable.

The treatment of the use of artificial illumination in the motion picture studio falls naturally into two main sub-divisions. The first includes a consideration of the characteristics of photographic materials and the response of these materials to the radiation of various intensities and qualities emitted by the light sources available. The second phase of the subject deals with the human eye, its characteristics and the possibility of injuries to any part of this organ resulting from either the excessive intensity or the quality of the radiation emitted by the sources used.

It is well known that two sources equal in visual intensity may differ enormously in their action upon the photographic plate. This follows from the fact that the photographic plate is sensitive to a spectral region, differing widely from that producing the visual sensation of light. If we consider a spectrum in which equal amounts of energy are radiated at each wavelength, it will be found that the wavelength producing the maximum visual sensation is approximately 550 $\mu\mu$, while the maximum response of the photographic plate occurs for a wave length of approximately 440 to 460 $\mu\mu$ Therefore, if the eye be used in judging the adequacy of illumination in the motion picture studio, serious errors may arise. It is of importance, therefore, to have available information as to the relative, visual and photographic efficiency of the illuminants which it is proposed to use for such work.

The judgment of the lighting effect in the motion picture studio

* Communication No. 135 from the Research Laboratory of the Eastman Kodak Co.

is made by visual observation. Since the photographic plate is not sensitive to the same spectral region as the eye, the rendition of tone values by the photographic material may be entirely different from the visual appearance especially in the case of chromatic objects.

In considering the effect of radiation on the eye of a person working under studio conditions, the possible injurious effects may be, for convenience, classified as due to two causes. The first of these that will be considered are the actual injurious effects due essentially to the quality of the radiation, while the second class of deletrious effects may be considered to arise essentially from the use of excessive intensities. The first part of this power will be devoted, therefore, to a discussion of the characteristics of the photographic materials as related to the illumination and to the conditions under which they are used in the motion picture studio, while the latter part will deal with the possible harmful effects to the eyes of workers in these studios, which arise either from the use of radiation of harmful quality or from the use of excessive intensities.

Terminology, Nomenclature and Units

In dealing with this subject which involves the consideration of the characteristics and the inter-relations existing between the characteristics of light sources, photographic materials and the retina, it is of considerable importance to develop a logical system of terminology and units. Unless this is done a great deal of confusion will inevitably result when attempting to formulate expressions showing the relation between various factors involved. Attention has already been devoted to the definition of terms used in photometry and a satisfactory system of units has been agreed upon. The Illuminating Engineering Society, through their Committee on Nomenclature and Standards, has published several reports dealing with this subject and insofar as is possible the definitions and symbols used to indicate the various quantities as adopted by this Society will be adhered to in this treatment of the subject.[1]

In the scientific literature dealing with photographic research, certain symbols have been used for many years as abbreviations for expressing the various factors involved and in some cases a conflict with the symbols used in photometry occurs. When, therefore, photography and photometry are dealt with in the same paper it becomes necessary to depart to a certain extent from the common usage of one of these sub-divisions of science. The only satisfactory solution in such a case is to compromise and adopt a terminology which will eliminate the confusion which necessarily would result from the use of the same symbols for two different factors. In the case of photography but little attention has been paid to developing a logical system of nomenclature and units, and in the present paper some proposals of new units which it is hoped will be of material assistance in dealing with photographic factors will be made. In the following paragraphs the various terms involved in the treatment of the subject will be defined with the unit applicable in each case.

Photometric Terms.

1. LIGHT. The term light is used either to express the visual sensation produced when radiant energy within the proper limits of wavelength impinges upon the retina, in reference to the radiant energy itself, or in some cases in reference to radiant energy of any wavelength (for instance, ultra violet light). The first usage is undoubtedly preferable and the use of the word light should be confined to this meaning. On this basis the definition may be stated as follows:

The term "light" is used to express the visual sensation produced normally when radiant flux within the proper limits of wavelength of sufficient intensity and of sufficient duration impinges on the retina.

2. RADIANT FLUX (J). The rate of flow of radiation evaluated with reference to energy. This is expressed in ergs per second or in watts.

3. LUMINOUS FLUX (F). The rate of flow of radiation evaluated with reference to visual sensation. This is expressed in lumens.

Lumen. (1) is the unit of luminous flux equal to the flux emitted in a unit solid angle (steradian) by a point source of unit luminous intensity.

4. VISIBILITY η_λ of radiation of a particular wavelength is the ratio of the luminous flux at that wavelength to the corresponding radiant flux.

5. LUMINOSITY (L) of a particular wavelength is the product of the visibility of that wavelength and the corresponding ordinate of the spectral curve of radiant flux and is represented by the ordinate of the spectral curve of luminous flux. This curve is called the spectral luminosity curve and is different with different sources.

6. LUMINOUS INTENSITY (I) of a source of light in a given direction is the solid angular density of the luminous flux emitted by the source in the direction considered, when the flux involved as far as computation and measurement are concerned acts as if it came from a point. Or, it is the luminous flux per unit solid angle from the source in the direction considered. The unit of luminous intensity is the candle.

Candle is the unit of luminous intensity maintained by the national laboratories of France, Great Britain and the United States.

Candle power (cp.) is a luminous intensity expressed in candles.

7. ILLUMINATION (N) of a surface at any point is luminous flux density at the surface at that point or the flux per unit of intercepting area. There are several units of illumination in use at the present time, among which are the lux, the phot, the foot candle. The meter candle which has been used almost exclusively in photographic work is equivalent to the lux. Of these the foot candle is probably most widely used in photometry.

Lux

Meter candle (mc.) is a unit of illumination equal to one lumen per square meter.

Foot candle (fc.) is the unit of illumination equal to one lumen per square foot.

8. BRIGHTNESS (B) of an element of luminous surface may be expressed in either of two ways (a) in terms of intensity (I), or (b) in terms of flux (F).

(a) Brightness in terms of the luminous intensity, I, (candle power) per unit of projected area of the surface (candle power brightness) corresponds to the defining equation

$$b_1 = \frac{dI}{dS \cos \theta} \qquad (1)$$

where θ is the angle between the normal to the surface and the line of sight.

(b) Brightness in terms of the flux (F) preceding from a unit area of the surface, on the assumption that the surface is a perfect diffuser (i. e., that it obeys the cosine law of emission or reflection) corresponds to the defining equation:

$$\frac{b}{F} = \frac{dF}{dS} \qquad (2)$$

Lambert is a unit of brightness in the lumen system and is the brightness of a perfectly diffusing surface emitting or reflecting 1 lumen per square centimeter. For most purposes the *millilambert* (ml), 0.001 lambert, is the preferable practical unit.

9. LUMINOUS EFFICIENCY (C) of any source is the ratio of the luminous flux to the radiant flux from the source and is expressed in lumens per watt.

10. MECHANICAL EQUIVALENT OF LIGHT is the ratio of radiant flux to luminous flux for the wavelength of maximum visibility, and is expressed in ergs per second per lumen, or in watts per lumen. It is the reciprocal of the maximum visibility.

11. REFLECTION FACTOR (R) of a body is the ratio of the flux reflected to the flux incident. The reflection may be regular, diffuse, or mixed. In regular reflection the flux is reflected at an angle of reflection equal to the angle of incidence. In diffuse reflection the flux is reflected in all directions. In the case of perfectly diffuse reflection, the distribution of the reflected flux is in accordance with Lambert's cosine law. In most practical cases there is a superposition of regular and diffuse reflection.

12. ABSORPTION FACTOR (Ab) of a body is the ratio of the flux absorbed by the body to the flux incident upon it.

13. TRANSMISSION FACTOR (T) is the ratio of the flux transmitted to the flux incident.

Photographic Units.

In considering photagraphic materials it is convenient to regard them as light sensitive receptors similar in many ways to the

retina of the eye. They are, however, not sensitive to the same wavelength range of radiation as the retina and hence in evaluating their response to a given stimulation this difference must be considered. It is thought that a system of nomenclature and units developed along the line of those already adopted for the visual response will be of value in systematizing measurements made with and relating to photographic materials. It is proposed to adopt the root "phot" as a basis upon which to build terms relating to photographic materials analagous to the usage of the word lumen and its derivatives in relation to the visual response. Thus the term "photic" will be used with reference to photographic materials in exactly the same sense as the word luminous as used relative to the eye. This provides us with such terms as "photic flux," "photic intensity," "photic efficiency," etc. It is proposed to call the fundamental unit the "photon" and to define this term in a manner exactly parallel to the definition already given to the lumen. On this basis we may therefore construct the following definition relative to photographic terms.

1. PHOTIC FLUX (G) is the rate of flow of radiation valuated with reference to photographic response and is expressed in "photons."

Photon (p) is the unit of photic flux equal to the flux emitted in a unit solid angle (steradian) by a point source of unit photic intensity.

2. PHOTIBILITY (A_λ) of radiation of a particular wavelength is the ratio of photic flux at that wavelength to the corresponding radiant flux.

3. PHOTOCITY (P) of a particular wavelength is the product of the photobility of that wavelength and the corresponding ordinate of the spectral curve of radiant flux and is represented by the ordinate of the spectral curve of photic flux. This curve is called the spectral photicity curve and is different for different sources.

4. PHOTIC EFFICIENCY (W) of any source is the ratio of the photic flux to the radiant flux from the source and is expressed in photons per watt.

The final decision as to the most useful and logical method of defining photographic terms analogous to luminous intensity brightness, illumination, etc., depends upon the outcome of certain experimental work now in progress. No definite proposals will be made therefore in the present paper for definition for these further terms which are necessary.

For many years the value of photographic exposure has been expressed in terms of meter candle seconds and a great deal of confusion has resulted from a lack of definite specification as to the spectral quality of the radiation used. For the time being the unit of exposure, therefore, will be taken as expressible in visual candle meter seconds, and upon this basis we may define as follows:

5. EXPOSURE (E) = illumination (N) x time (t).

It is at this point that a conflict between photography and

photometry in the usage of E as a symbol occurs. This symbol has been used for so many years in the literature of photography as a symbol for exposure that it is quite impossible to propose any substitute. It is proposed therefore to retain E as a symbol for exposure and to adopt as a symbol for illumination the letter N.

6. DENSITY (D) is used in photography as a designation of the light stopping power of a silver deposit and is defined by the equation

$$D = \log O = \log \frac{F_1}{F_2} \qquad (3)$$

Where—F_1 = flux incident upon the deposit considered
F_2 = flux transmitted by the deposit considered
O = opacity of the deposit considered.

The value of density depends to a certain extent upon the conditions of illumination and observation under which measurements are made. Since a silver deposit is composed of small particles of metallic silver embedded in the matrix of gelatine, the light transmitted is scattered to a certain extent. The value of density obtained therefore depends upon whether the measurement is made with parallel or diffuse illumination. It should be pointed out also that density as measured visually does not always correspond in magnitude with the density as regarded from the photographic standpoint.[2]

As a means of convenient reference, the terms thus far defined are summarized in Table 1.

TABLE 1

Term	*Symbol*	*Unit*	*Abbreviation*
Radiant Flux	J	Watt	—
Luminous Flux	F	Lumen	1
Visibility	V^λ	Lumens/Watt	—
Luminosity	L	Lumens/Watt	—
Luminous Intensity	I	Candle	c.p.
Illumination	N	Meter Candle	m.c.
Brightness	B	Milli-lambert	m.l.
Luminous Efficiency	C	Lumens/Watt	—
Reflection Factor	R		
Transmission Factor	T		
Absorption Factor	Ab		
Photic Flux	G	Photon	p.
Photibility	A^λ	Photons/Watt	—
Photicity	P	Photons/Watt	—
Exposure	E	Meter Candle Seconds	mcs.
Density	D		
Opacity	O		
Time	t	Second	sec.
Distance	d	Meter	m.

General Theory

Before taking up the experimental and more practical phases of the problem, it may be well to consider briefly the general functions which must be considered in the theoretical evaluation of visual and photographic efficiencies. These functions are most clearly represented by the aid of curves showing their forms.

Among the functions necessary for the solution of this problem are those expressing the relation (a) between the wavelength and the energy radiated at these wavelengths by the various illuminants, (b) between the retinal response and the energy at various wavelengths, (c) between the photographic response and energy radiatd at various wavelengths, (d) between the transmission values and wavelength for the various media which must be interposed between the sources of illumination and the photographic plate during operation. For convenience, these functions with their symbols and meanings will be tabulated as follows:

$J = f\,\lambda$ = spectral energy distribution of the illuminant.

$T = f\,\lambda$ = spectral transmission function of the media between the source and the photographic plate.

$V = f\,\lambda$ = visibility function of the retina.

$A = f\,\lambda$ = spectral distribution of sensitivity for the photographic plate (photobility).

The symbols $J\lambda$, $T\lambda$, etc., are used to designate the values of these various functions at some particular wavelength, λ. Typical illustrations of this are shown in Figure 1, curve C representing the energy distribution for an incandescent tungsten lamp. Curve D is the visibility function of the human eye, curve B is the spectral transmission for a typical sample of glass. Curve A is the spectral sensitivity of cine negative film. The dotted portions of the curves represent regions in which the values are somewhat doubtful, having been determined by extrapolation rather than actual measurements.

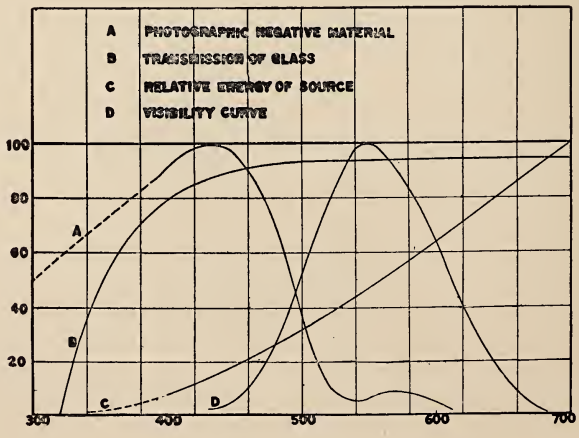

Fig. 1—Spectral Distribution Curves.

The ordinate values of the energy function are in terms of relative energy, while those of the glass transmission are the ratio of the transmitted to the incident radiation. The ordinates of the visibility function are relative brightnesses of an equal energy source plotted with the maximum ordinate equal to unity. The ordinates of the photobility function represent relative sensitivities also plotted with the maximum ordinate equal to unity. The visual efficiency of any illuminant is given by,

$$\frac{\int_0^\infty J_\lambda V_\lambda \, d\lambda}{\int_0^\infty J_\lambda \, d\lambda} = C \tag{4}$$

If this value be computed for various illuminants their relative efficiencies from the visual standpoint are determined. The photo efficiency of an illuminant is given by the expression:

$$\frac{\int_0^\infty J_\lambda A_\lambda \, d\lambda}{\int_0^\infty J_\lambda \, d\lambda} = W \tag{5}$$

The determination of this value gives the photic efficiency of the illuminant in terms of photons per watt. A consideration of these functions and their forms shows immediately why such a discrepancy may exist between the relative efficiency of various illuminants when determined from the visual and photographic standpoints. In order to illustrate this, curves in Figures 2 and 3 are given. In Figure 2 the luminosity curve (L) is determined for a tungsten lamp operating at 22 lumens per watt, this distribution of energy being represented by the curve J. V is the visibility of radiation. It will be noted that the maximum of the luminosity curve

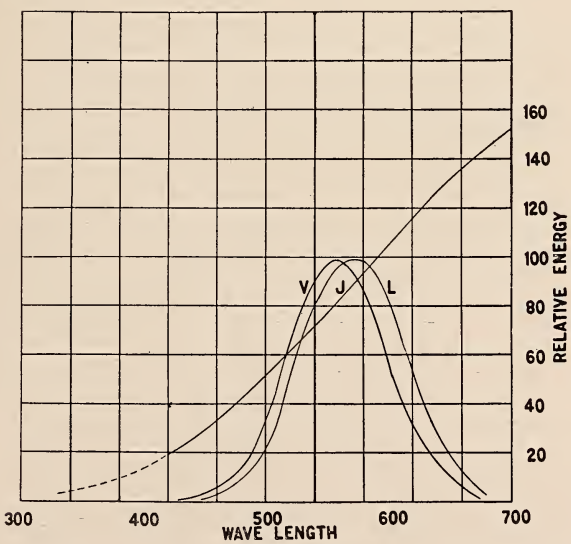

Fig. 2—Luminosity Curve for Incandescent Tungsten at 22 Lumens per Watt.

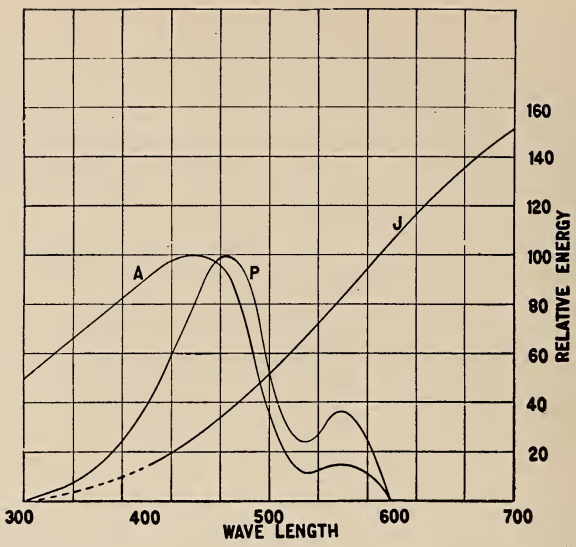

Fig. 3—Cine Film Photicity Curve for Incandescent Tungsten at 22 Lumens per Watt.

comes at approximately 580 $\mu\mu$. In Figure 3 the photicity curve P of cine negative film for the same source is shown, A representing the photibility of radiation for the photographic material under consideration. It will be noted that the maximum of the photicity curve falls at 465 with a secondary maximum of 560 $\mu\mu$. In computing the photicity curve shown in Figure 3, no account is taken of absorption by such materials as glass lenses in the photographic system.

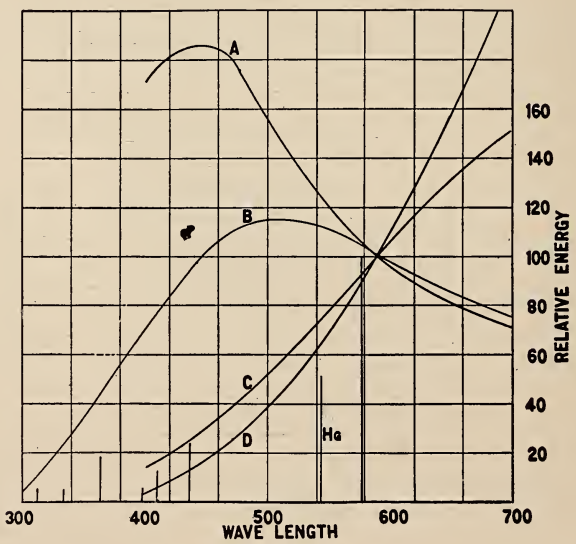

Fig. 4—Curves Showing Spectral Distribution of Energy.

In Figure 4 are shown four typical spectral energy distribution curves, A being for skylight, B for sunlight, C for incandescent tungsten at 22 lumens per watt and D for incandescent tungsten at 7.9 lumens per watt (approximately 1.25 watts per candle). The distribution of energy in the spectrum of the quartz mercury vapor lamp is shown by the heavy vertical lines marked "Hg." The position of these lines represent the wavelengths while the height is proportional to the energy radiated at that wave length. In Figure 5 are given additional energy curves, curve A representing the spectral distribution of energy in the flame of the Eastman standard acetylene burner. Curve B is for the DC open arc. A complete and precise knowledge of the various functions considered would make it possible to calculate directly the relative effiiciencies of various illuminants when used in connection with photographic materials of various spectral sensitivity. Unfortunately some of these functions are not precisely known and their quantitative determination is beset with considerable difficulty. In practice it is simpler and more precise to measure relative efficiencies by direct methods.

Relative Efficiencies of Illuminants.

The methods employed for obtaining the desired ratios are essentially those used in the determination of plate speeds and will be outlined briefly in the following paragraphs.

This general class of work is termed "sensitometry"[3] and the plates being tested are exposed in instruments called "sensitometers."[4, 5] Such instruments provide a means for subjecting various portions of the photographic plate to exposure of precisely

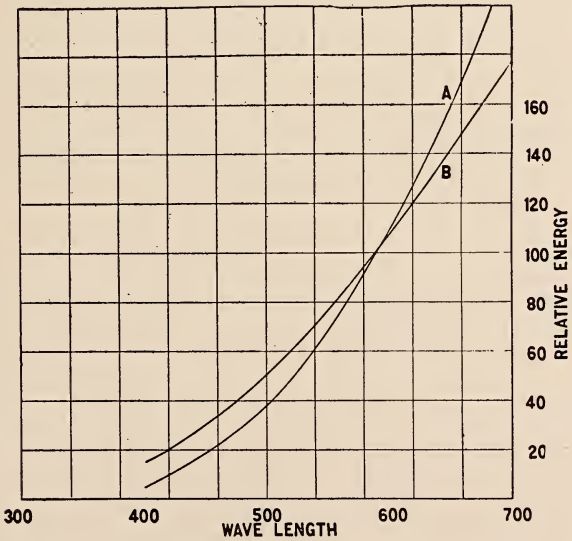

Fig. 5—Curves Showing Spectral Distribution of Energy.

known and variable values. If a strip of a photographic plate be exposed in such a way that successive areas receive exposures increasing by consecutive powers of two, it will be found upon development that a series of spots of increasing opacity are obtained. By measuring the density of each of these spots, plotting the value obtained against the logarithm of the exposures given, a curve is obtained which is known as the "characteristic curve" of the plate. The curves shown in Figure 6 were obtained in this manner. The curve designated by the letters AB was obtained from a strip that was developed for three minutes in a standard developer, while that designated by the letters A′ B′ was obtained by a six minute development. It is customary to express the blackness or opacity of a photographic deposit in terms of its "density," D.

It will be noted with reference to Figure 6 that the portion of the curve between the points A and B is a straight line. This line extended cuts the log exposure axis at O and the value of expos-

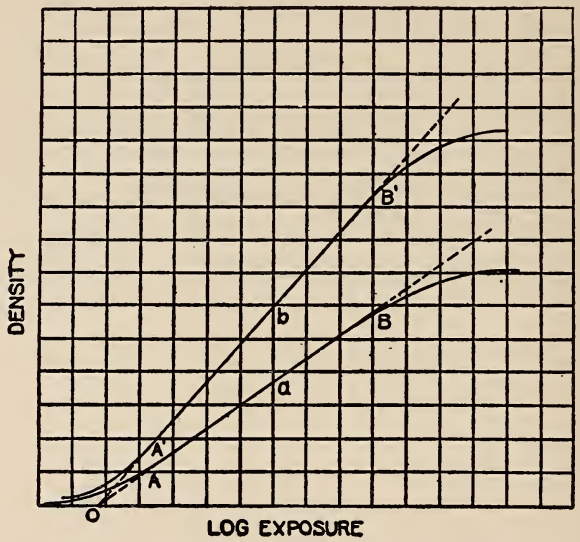

Fig. 6—Characteristic Curves of Photographic Materials.

ure at the point O is termed the "inertia" of the plate. It will be noted further that the straight line portion of both curves shown in Figure 6 cuts the log E axis at the same point, thus showing that "inertia" is independent of the time of development. This is true only under certain conditions which depend upon the constitution of the developing solution. It should be pointed out that inertia is expressed in exposure units and that exposure E is equal to the product of the time exposure (t) by the illumination (N) incident on the plate during exposure. Illumination is usually expressed in meter candles and time in seconds exposure. Consequently, inertia is in meter candle seconds. Since the candle is the unit of intensity based upon the visibility of radiation values, it is a visual unit. Pho-

tographic exposures are normally expressed in terms of visual units. The inertia value is proportional to the insensitivity of the plate and the reciprocal of the inertia is proportional to the sensitivity or speed of the plates. Speed numbers for the plate are obtained by multiplying the reciprocal of inertia by some arbitrarily chosen constant. As stated previously the inertia value does not in general depend upon the time of development or upon the constitution, concentration, or temperature of the developer used.

Since the inertia is expressed in terms of visual units, it will necessarily depend upon the quality of the light used in making exposure. Thus, if the plate be sensitive to blue light only, as is practically the case of ordinary photographic materials, a lower inertia (multiplying number) will be obtained when a bluish light is used than when one of yellow color is employed. The fact that the inertia value depends upon the quality of light to which the plate is exposed offers a very convenient means of measuring the photographic efficiency of illumination.

In testing plates for speed the light source is kept constant in quality and intensity and the reciprocal of the inertia value obtained is proportional to the speed of the plate. Now, if the plate speed be kept constant and the quality of the light changed by using various sources, the reciprocal of the inertia values may be taken as directly proportional to the photographic efficiency for the various sources. This may be illustrated by Figure 7. Let curve A be one obtained

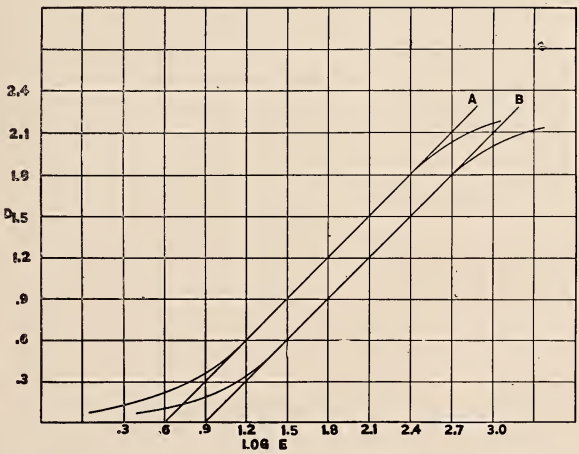

Fig. 7—Characteristic Curves of Photographic Materials.

by exposure to a source such as the high efficiency tungsten lamp and curve B one obtained by use of an old type carbon incandescent light which is yellowish as compared with a tungsten lamp. In the case shown the inertia value for curve A is only one-half that of curve B. Thus, for equal candle meter seconds exposure, the photographic effect of the tungsten is twice as great for that of the carbon and if we arbitrarily assume that the efficiency of the tungsten

lamp is 100% then that of the carbons is 50%. This may be expressed in the following manner. Let i_1 represent the inertia value for curve B and i_2 that for curve A. Then if it be desired to express the efficiency of the source B in terms of source A, it is only necessary to write Wv (relative photographic efficiency)

$$= \frac{i_1}{i_2} \times 100 \qquad (6)$$

In making comparisons of efficiency in this manner, it is necessary to choose some source as a standard. Since in practical work a great majority of the plates and film used are exposed to light from the sun, it seems most logical to adopt that as the standard upon which to judge all artificial illuminants. Perhaps this argument does not apply as completely in the field of motion picture work, but since it is very undesirable to have one standard of comparison in this field and another in the case of landscape and amateur photography, it seems advisable to adopt the sunlight as a standard in terms of which to express the efficiency of all artificial illuminants.

Space will not be devoted at this time to a detailed discussion of the sensitometric apparatus and methods used in the determination of the efficiency given in the following tables. For these details the reader is referred to previous publications on the subject,[6]

In Table 2 are given the results of measurements made with a large number of different sources using the three typical classes of photographic materials. These may be described in general as follows. The ordinary plate is sensitive only to blue light while the orthochromatic is sensitive to both blue and green and the panchromatic is sensitive to blue, green and red. The values given for each photographic material in the column marked S are the reciprocals of the inertia values obtained with various sources. The values in the column marked Wv are relative efficiencies in terms of sunlight as 100%. Since inertia values are expressed in meter candle seconds, it follows that these efficiencies are in terms of visual units.

TABLE 2.
Relative Photic Efficiency = Wy

No.	Source	Visual Efficiency Lumens Watt	Photographic Materials: Ordinary	Orthochromatic	Panchromatic
1.	Sun	150	100	100	100
2.	Sky	...	181	155	130
3.	Acetylene	0.7	30	44	52
4.	Acetylene screened	0.07	81	85	89
5.	Pentane	0.45	18	28	42
6.	Mercury arc—quartz	40.0	600	500	367
7.	Mercury arc—nultra glass	35.0	218	195	165
8.	Mercury arc—crown glass	37.0	324	275	249
9.	Carbon arc—ordinary	12.0	126	112	104
10.	Carbon arc—white flame	29.0	257	234	215
11.	Carbon arc—enclosed	9.0	175	177	165
12.	Carbon arc—"Aristo"	12.0	796	1070	744
13.	Magnetite arc	18.0	106	115	82
14.	Carbon glow lamp	2.44	23	32	42
	Carbon glow lamp	3.16	25	35	45
15.	Tungsten evacuated	8.0	33	41	50
	Tungsten evacuated	9.9	37	45	53
16.	Tungsten nitrogen—filled	16.6	56	62	70
	Tungsten nitrogen—filled	21.6	64	68	76
17.	Tungsten blue bulb	8.9	95	87	95
	Tungsten blue bulb	11.0	108	99	106
18.	Mercury-vapor	23.0	316	354	273

For instance, a Wv value of 50 indicates that with the illumination to which the value applies the illumination on the object must be twice as great as would be required with sunlight to obtain this same photographic effect. Since the efficiency in terms of energy consumption is of considerable interest, the values given in Table 2 have been reduced to that basis and are given in Table 3. The luminous flux incident upon unit area (1 sq. cm.) at a meter distance from the source of 1 mean spherical candle power is

$$\frac{4\pi}{4\pi r^2} = \frac{1}{100^2 \text{ lumens}} \qquad (7)$$

This is the value of the luminous flux incident upon unit area of the surface on which the illumination is 1.0 meter candles. If the inertia expressed in terms of energy be denoted by the symbol

$i_e = \frac{i}{100^2}$, this is expressed in terms of $\frac{\text{lumens seconds}}{\text{cm.}^2}$

Now, if the efficiency of the source used be C (in $\frac{\text{lumens}}{\text{watts}}$), the value remains the same when expressed in $\frac{\text{lumen seconds}}{\text{watt second}}$, $\frac{I}{C}$ is the efficiency in $\frac{\text{watt seconds}}{\text{lumen seconds}}$, and

$$i_e = \frac{i \text{ (in m.c.s.)}}{100^2} \times \frac{1}{C} = \frac{\text{watts seconds}}{\text{cm}^2} \qquad (8)$$

$$i_e = \frac{i \text{ (in m.c.s.)}}{100^2} \times \frac{10^7}{C} = \frac{\text{ergs}}{\text{cm.}^2} \qquad (9)$$

i_e is, therefore, the inertia value expressed in ergs consumed at the source per cm² at the plate. This value is inversely proportional to the photic efficiency of the source when used on that particular plate. The photic efficiency may be obtained, therefore, by taking the reciprocal of i_e.

TABLE 3.
Relative Photic Efficiency = We

No.	Source	Visual Efficiency Lumens Watt	Photographic Materials: Ordinary	Ortho-chromatic	Pan-chromatic
1.	Sun	150.0	100.0	100.0	100.0
2.	Sky	.....	.....	.....	.....
3.	Acetylene	0.7	0.14	0.21	0.24
4.	Acetylene screened	0.07	0.04	0.040	0.042
5.	Pentane	0.45	0.05	0.9	0.13
6.	Mercury arc—quartz	40.0	158.0	130.0	99.0
7.	Mercury arc—"nultra"	35.0	50.0	47.0	39.0
8.	Mercury arc—crown	37.0	79.0	68.0	62.0
9.	Carbon arc—ordinary	12.0	10.0	9.0	8.5
10.	Carbon arc—white flame	29.0	52.0	45.0	42.0
11.	Carbon arc—enclosed	9.0	11.0	11.0	10.0
12.	Carbon arc—"Aristo"	12.0	62.0	86.0	60.0
13.	Magnetite arc	18.0	12.0	14.0	10.0
14.	Carbon glow	2.44	0.37	0.52	0.68
	Carbon glow	3.16	0.51	0.74	0.95
15.	Tungsten vacuum	8.0	1.7	2.2	2.7
	Tungsten vacuum	9.9	2.4	3.0	3.50
16.	Tungsten-nitrogen	16.6	6.1	6.8	7.7
	Tungsten-nitrogen	21.6	8.9	9.8	11.0
17.	Tungsten blue bulb	8.9	5.5	5.2	5.6
	Tungsten blue bulb	11.0	7.8	7.31	7.9
18.	Mercury-vapor	23.0	47.0	54.0	42.0

In order to make the results obtained on different plates comparable with each other, it is necessary to use some source as a standard. Sunlight is used as before, its efficiency being taken as 100% on each plate.

The values of visual efficiency for many sources were not measured directly, but were estimated from the last available data found in the literature on the subject. The values tabulated in Table 3 are:

$$i_e = \frac{i\ (\text{m.c.s.})\ 10^3}{E} = \frac{\text{ergs}}{\text{cm.}^2} \tag{10}$$

$$W_e = \frac{1{,}000\ i_e\ (\text{for sun})}{i_e\ (\text{for particular source})} \tag{11}$$

The values obtained in this manner are tabulated in Table 3, the values of W_e being proportional to the photographic effect obtained with the various sources for equivalent energy expeditures.

In the case of incandescent lamps, the quality of the light emitted is dependent upon the temperature of the filament and therefore upon the voltage applied. As the applied voltage is increased the temperature rises and the amount of energy radiated in the blue increases relatively to that radiated in the red end of the spectrum. The photic efficiency, therefore, is a function of the applied voltage and it seemed worth while to obtain a complete photic efficiency-voltage characteristic for some of the more commonly used commercial lamps. For this work a 500 watt gas filled lamp with a normal rating of 120 volts was chosen. This was operated at various voltages ranging from that which gave a visual efficiency of 2.4 lumens per watt up to 25.0 lumens per watt. The photic efficiency is determined throughout this range with ordinary, orthochromatic and panchromatic materials. In Table 4 the results of

TABLE 4.

Source: Gas-filled tungsten: Watts, 500
Volts, 120
Reduction factor 88.

Exposure: 15 meter candle seconds: Illumination = 0.10 m.c.
Time = 150 sec.

C (lumens/watts)	Photographic Material: Ordinary W_V	Orthochromatic W_V	Panchromatic W_V
2.4	35	44	52
5.6	40	45	57
8.6	46	52	59
15.4	55	60	67
19.9	62	67	75
22.6	64	70	75
25.0	67	72	78

these measurements are tabulated. In the first column are the values of visual efficiency (C) and in the columns marked W_V are the photic efficiencies for the various materials, W_V being the photic efficiency computed on the basis of equal visual intensities and with sunlight as 100%. The visual efficiency for this particular lamp at its rated voltage (that is, 120) was approximately 16.0 lumens per watt. It will be noted that the value of W_V increases appreciably as the visual efficiency increases and since these values are computed on the basis of equal visual and photic intensities it follows that the photic intensity increases at a greater rate than the visual. In some cases,

therefore, it may be advisable to operate this type of lamp at a voltage somewhat above its normal rating, at least while exposures are being made. The operation of these lamps above their normal voltage necessarily shortens their effective life, but in view of the appreciable increase in photic intensity such procedure may be justified.

During the past few years, the flame arc, [7], [8], [9], has been developed to a great extent and many different types of carbons have been placed on the market. By using these carbons a marked variation in the quality of the light can be obtained. In certain branches of cinematography this control of quality may be found of considerable advantage. This applies particularly to photo-engraving work and to the production of color motion pictures. In both of these fields, it is necessary to use color filters in making the negatives and it seems quite possible that an arc radiating excessively in certain regions may be found of advantage. Measurements of photic efficiency were therefore made using several different types of flame carbons. In this group of measurements panchromatic plates were used entirely since it was desired to obtain measurements relative to the efficiencies of these sources when used in connection with typical three-color taking filters. The same sensitometric procedure was employed as was used in the previous work. The arc lamp used was of a simple hand adjusted open type holding the carbons in a vertical position. After considering the conditions under which arc lamps are operated for commercial work, it was decided that the current consumption of 25 amperes with a potential of 50 volts across the arc represented an average condition and these values were closely adhered to throughout. The arc was operated on a 110 volt d.c. line. A plain cored negative above with a 10.0 mm. flame carbon below was used as standard trim. Sensitometric measurements were made using unfiltered light and for each of the three standard tri-color taking filters Wratten No. 25 being the red, No. 58 the green, and No. 49 the blue. For the complete spectrophotometric transmission characteristics the reader is referred to the filter booklet dealing with the characteristics of the Wratten filters.

In Table 5 are given the values of relative efficiency on the basis of equal visual intensities, the values in column 1 being for an unfiltered arc and those in columns 2, 3 and 4 for the filters as indicated. Effciency measurements for these sources were not made on ordinary and orthochromatic materials.

In Table 6 are tabulated the values of relative efficiency on the basis of equal energy consumption.

TABLE 5.

Source	Efficiency	No Filter		Blue (49)		Green (58)		Rec (25)	
	C	i	Wv	i	Wv	i	Wv	i	Wv
Sun	150	.024	100	.15	100	.24	100	.33	100
White Flame Arc	53	.012	200	.10	150	.34	69	.33	100
Pearl Flame Arc	61	.019	124	.14	106	.62	38	.33	100
Yellow Flame Arc	94	.041	54	.37	40	.71	34	.22	147
Red Flame Arc	41	.020	122	.16	100	.46	52	.10	330
Blue Flame Arc	21	.009	270	.09	166	.38	62	.28	120
High Intensity White Flame Arc	86	.020	122	.15	100	.39	62	.33	100

TABLE 6.

Source	Efficiency	No Filter		Blue (49)		Green (58)		Red (25)	
	C	ie	We	ie	We	ie	We	ie	We
Sun	150	.16	100	1.0	100	1.6	100	2.2	100
White	53	.23	70	1.9	53	6.4	25	6.2	35
Pearl	61	.31	52	2.3	43	10.0	16	5.4	41
Yellow	94	.43	37	3.9	26	7.4	22	2.3	96
Red	41	.49	33	4.0	25	11.0	15	2.4	88
Blue	21	.43	37	4.3	23	18.0	9	13.0	17
High Intensity White	86	.23	70	1.7	59	4.5	36	3.8	60

Transmission of Photographic Lenses.

Another factor which must be considered in a discussion of the requisite illumination is the relation between the brightness of the object being photographed and the illumination on the photographic plate at the point where the image of this object is formed by the lens of a taking camera. Since lenses are composed of various members of components each of which is bounded by two glass air surfaces, a certain amount of light is reflected at each of these boundaries and hence does not reach the plate as image forming light. The amount of light lost in this way depends upon the number of free glass area surfaces in the lens and to a certain extent upon the surface curvatures. In some cases components are cemented together with Canada balsam and this also may act as an absorbent of radiant energy. The glass itelf absorbs a certain amount of radiation in the visible spectrum and this absorption increases rapidly in the ultra violet. In Figure 8 is given a spectrophotometric transmission curve for the lens elements composing a well-known type of photographic objective. It will be seen that even in the visible spectrum the transmission is only 75% and this decreases very rapidly between 300 and 400 $\mu\mu$.

Aside from these losses by reflection and absorption, the relation between the object brightness and the illumination incident on the photographic plate can be computed theoretically on strictly geometrical consideration. This matter has been dealt with in detail by P. G. Nutting[10] and later by G. W. Moffitt.[11] Using the formula relative to object brightness (B_0) and the illumination of the image (N_0) the values in Table 7 are computed. It will be noted that the value of this factor varies but little with object distance nor is the variation with the focal length of the lens appreciable. Taking the values therefore for a lens having a focal length of 50 ml. and an object distance of 25 feet the curves shown in Figure 8 are plotted. The ordinate values are of the ratio $\frac{Nx}{Bo}$ (theoretical), while the abscissae values are in terms of the stop number, that is, the ratio of the focal length to the diameter of the limiting diaphragm. The ordinate values apply to the left hand segment of the curve while for the right hand segment of the curve the ordinate values as indicated should be divided by ten.

It will be seen from the previous discussion that in order to obtain a factor by which the object brightness must be multiplied in order to obtain the illumination on the image plane, two factors must be taken into consideration, one of which takes into account what

TABLE 7.

Variation in $\frac{Nx}{Bo}$ (theoretical) with stop, object distance, and focal length.

The approximate formula is $\frac{Nx}{B_0} = \frac{II}{4S^2} - \frac{II}{2S^2} - \frac{f}{u}$,

where S is the "f number"

		(Object Distance, u.) 6'	10'	25'	50'	100'	00
S = 2	f = 40mm.	0.1878	0.1912	0.1943	0.1953	0.1958	0.1964
	f = 50mm.	0.1856	0.1899	0.1938	0.1951	0.1957	0.1964
	f = 75mm.	0.1802	0.1867	0.1925	0.1944	0.1954	0.1964
S = 4	f = 40mm.	0.04694	0.04780	0.04857	0.04883	0.04896	0.04909
	f = 50mm.	0.04641	0.04728	0.04845	0.04877	0.04893	0.04909
	f = 75mm.	0.04506	0.04667	0.04812	0.04861	0.04885	0.04909
S = 8	f = 40mm.	0.01173	0.01195	0.01214	0.01221	0.01224	0.01227
	f = 50mm.	0.01140	0.01187	0.01211	0.01219	0.01223	0.01227
	f = 75mm.	0.01126	0.01167	0.01203	0.01215	0.01221	0.01227
S = 16	f = 40mm.	0.002934	0.002987	0.003036	0.003052	0.003060	0.003068
	f = 50mm.	0.002900	0.002967	0.003028	0.003048	0.003058	0.003068
	f = 75mm.	0.002816	0.002917	0.003008	0.003038	0.003053	0.003068
S = 32	f = 40mm.	0.000733	0.000747	0.000759	0.000763	0.000765	0.000767
	f = 50mm.	0.000725	0.000742	0.000757	0.000762	0.000764	0.000767
	f = 75mm.	0.000704	0.000729	0.000752	0.000759	0.000753	0.000767

we may term the physical characteristics of the image forming system such as the absorption in the glass and other materials composing the lens and reflection from the lens surfaces. The other factor depends upon what we may term the geometrical characteristics of the image forming system. Let the former of these two factors be designated by the symbol Z_p and the latter by the symbol Z_g. Then if Z be used to denote the number which satisfies the equation $Z. B_0 = N_x$, $Z = Z_g. Z_p$. The value of $Z_g = N_x$ (theoretical) are as given in Table 7 and in Figure 9. If B_0 be expressed in lamberts, N_x will be in terms of photos.

The absorption depending upon the physical characteristics of the lens (that is, the value of Z_p) has been measured and some values published for various lenses. [10]. From the available data which show variations in transmission (Z_p) from .53 to .57, it seems that a fairly reasonable average value to assume for cinematograph lenses is $Z_p = .65$.

Calculation of Illumination Required.

Having considered the factors which determine the relation

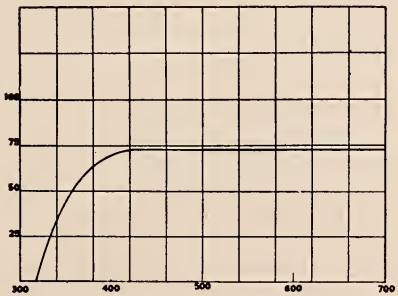

Fig. 8—Spectrophotometric Transmission Curve of Photographic Objective.

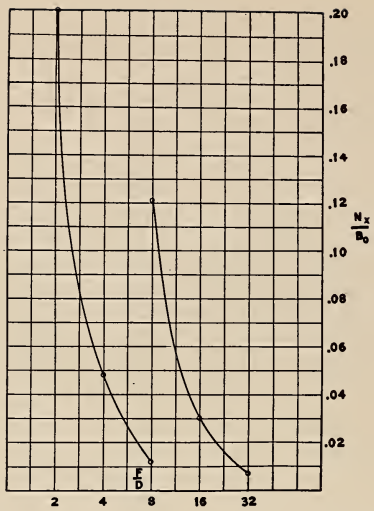

Fig. 9—Brightness Ratio Curves for Lenses at Various Apertures.

between the visual brightness of an object and the photographic brightness of an image for that object formed on the plate by the optical system which must be employed in the taking of motion pictures, it is possible now to point out definitely a method by which the exposure required under a given system of conditions may be computed, or, on the other hand, if the exposure time is fixed, it is possible to compute the required illumination. One of the factors which must be considered in this is the speed or sensitivity of the photographic material being used.

In Fig. 10 is given a typical characteristic curve for cine negative film, the abscissae values being in terms of log exposure.

In Fig. 11 is given a similar curve for cine panchromatic negative films. These two materials represent almost completely the types of photographic materials used for making the negative in motion picture work. Before considering further the method of computing either exposure time or the requisite illumination as may be desired, it may be well, for the sake of clearness, to tabulate the factors which must be considered. These factors are as follows and for the sake of convenience are designated by the symbols as indicated.

B_0 (min.) = the brightness of the object in the deepest shadow which it is desired to reproduce.

D (min.) = minimum density desired in the negative.

Log E (min.) = exposure indicated by the characteristic curve of the material which corresponds to $D_{min.}$

t = exposure time.

W_v = Relative photic efficiency of illuminant used.

N_x = (min.) = the illumination on the negative material at the point corresponding to the object brightness B_0 (min.)

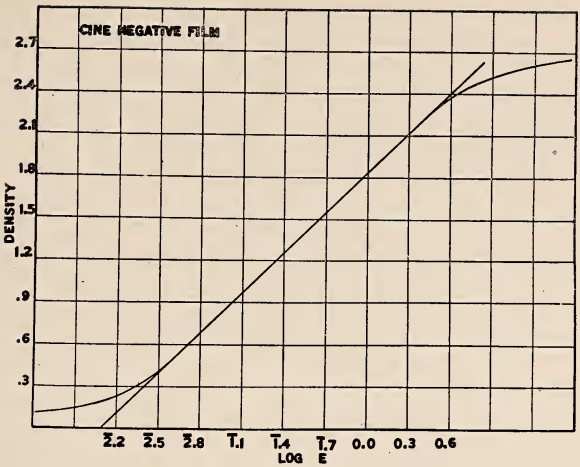

Fig. 10—Characteristic Curve for Cine Negative Film.

The following relations between these constant found

$$N_x \text{ (min.)} = Z \,.\, B_0 \text{ (min.)} \tag{12}$$

$$N_x \text{ (min.)} \,.\, t = E_x \text{ (min.)} = t \,.\, B_0 \text{ (min.)} \,.\, Z \tag{13}$$

$$B_0 \text{ (min.)} = \frac{E_x \text{ (min.)}}{t \,.\, Z} \tag{14}$$

This equation is based on the assumption that the object on which the minimum brightness is measured is non-selective in its reflection characteristics. It further assumes that there is no selectively absorbing material between the light source and the object illuminated or between the object and the taking camera. No account is taken in this formula of the relative photic efficiency of the illuminant, it being assumed that the quality of a light used in the

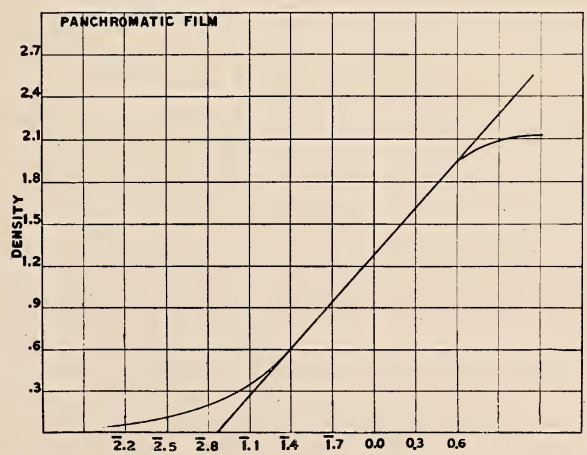

Fig. 11—Characteristic Curve for Cine Panchromatic Film.

determination of the characteristic curve of the material from which the value E_x is taken is the same as that used in illuminating the object on which the measurement of B_o (min.) is made. Now sensitometric tests of photographic materials are made by using light of sunlight quality. Therefore, on the basis of our previous definition of relative photic efficiency, the efficiency value of this illuminant is 100% or expressed decimally 1.0.

In order to account for the use of illuminants other than sunlight, it is necessary to introduce into the equation the relative photic efficiency and this may be done by multiplying the first members of the equation by W_v as previously defined. A complete expression for the minimum object brightness therefore becomes

$$B_o \text{ (min.)} = \frac{E_x \text{ (min.)}}{t \cdot Z} \quad \frac{1}{W_v} \tag{15}$$

In a like manner a term to take care of selective reflection from the object may be introduced as well as terms to compensate for the use of selectively transmitting screens either between the light sources and the object or the object and the taking camera. For the sake of simplicity, however, let us assume that the object considered is non-selective in its reflection characteristics and further that there are no selective absorbing screens between the light source and the object or between the object and the taking camera.

Now in practice it is usually desired to render the deepest shadow of the object by a density in the negative as low as is possible. By an examination of the curve in Figure 10, it will be seen that the effective portion of the curve ends at a density of approximately .2, since for lower densities the gradient of the curve is so low as to be of rather doubtful use in the reproduction of tone difference. We may take it, therefore, that in practice a density of .2 should be allowed to represent the deepest shadow of the object. The log E value corresponding to this will be found in the case of the material represented by a curve in Figure 9 to be -2.1, the corresponding value of E being .5125 (mcs.).

Let us assume that a lens working at f 3.5 is to be used having a transmission value (Z) of .65. Referring to Figure 9, it will be found that the value of Nx (theoretical), that is of Z_g is equal to .06. This factor converts object brightness expressed in lamberts to image illumination expressed in phots, and as stated previously, in order to convert brightness in millilamberts into image illumination in meter candles, this factor must be divided by ten. Since exposure (E) is expressed at the present time in terms of meter candle seconds, it is necessary to use the value of Z_g which will express the image brightness in terms of meter candles. Assume further that the scene being photographed is illuminated by nitrogen filled tungsten lamps operated at 25.0 lumens per watt. Referring to Table 4 it will be seen that the relative photographic efficiency (W_v) for light of this quality is .67. The assumptions that have

been made are such as might be met with in practice and the values of the factors assumed are as follows:

E_x (min.) = .0125 (mcs)
t = .031 (sec.)
Z_g = .006
Z_p = .67
Z = .06 . .67 = .004
W_v = .67

Substituting these values in equation 15, we have

$$B_0 \text{ (min.) ml.} = \frac{.0125}{.031 \;.\; .006 \;.\; .67} = 100. \text{ ml.} \qquad (16)$$

If now the reflecting power of the portion of the object which forms the deepest shadow be known, the required incident illumination may be computed. Assume, for example, that the material which forms the deepest shadow has a reflecting power of .05. The equation relating to brightness, reflecting power and illumination is as follows:

$$B \text{ (ml.)} = \frac{R \;.\; N \text{ (m.c.s.)}}{10} \qquad (17)$$

Substituting we have

$$100 = \frac{.05 \;.\; N}{10} \qquad \text{or } N = 20{,}000 \text{ m.c.s.}$$

In the computation thus far, no account has been taken of selectively absorbing materials between the light source and the object or between the object and the lens. In case such absorbing media are present their effect can be taken into account by inserting in the formula their transmission values if known and properly determined. It will be noted from a consideration of the treatment of the subject thus far given that there is at many points a lack of adequate quantitative data for a complete and precise computation of desired values. It is evident also that at the present time the system of units which must be used is somewhat heterogenous and unwieldy. It is realized that the treatment is not complete from the practical standpoint but it is hoped that the material presented will give the reader a general idea of the various factors involved and of the inter-relation existing between them.

Turning now to a consideration of the subject from the standpoint of the effect of various illuminants upon the eyes of persons who must work under the illumination condition existing in the studio, we find that the subject matter may be divided for convenience into two parts. The first deals with the question of injurious or harmful effects arising from the radiation which may be ascribed as inherently due to the quality of the radiation, and the second consisting of a discussion of the injury or fatigue resulting from unduly high intensities and contrast.

Within recent years much has been written dealing with the injurious effects of ultra violet and infra red radiation. Roughly speaking any radiation of wavelengths shorter than 400 $\mu\mu$ is termed ultra violet, while that of wavelengths longer than 700 $\mu\mu$ is referred to as infra red. It has been stated that cataract is in many cases caused by the action of unduly high intensities of infra red radiation,

and to the action of ultra violet radiation has been attributed many serious injuries to the retina and to other parts of the eye. Many papers dealing with this subject have appeared in the technical publications and no attempt will be made at this time to give a complete review of the literature. A very complete bibliography on this subject will be found in the Transactions of the Illuminating Engineering Society, 1914, p. 311 to 331, and a report of a very thorough investigation of the subject including a review of previous work appeared in the Proceedings of the American Academy of Arts and Science, Vol. 51 (1916), p. 630-817. A very interesting and complete treatment of the subject was presented at the September, 1921, convention of the Illuminating Engineering Society by F. H. Verhoeff and Louis Bell. This paper has not as yet been published but will doubtless appear in an early issue of the Transactions of that Society. From the results of the various researches that have been carried out on this subject the following conclusions may be drawn:

It has been definitely established that radiation which is actually destructive in its action on living tissues is confined to wavelengths shorter than 305 $\mu\mu$. This radiation is almost completely absorbed by the cornea, crystalline lens, and vitreous humor of the eye and hence can never reach the retina in sufficient intensities to cause injury except when very intense sources of this radiation are focused upon the retina by optical systems which transmit these wavelengths. It is therefore apparent that under practical conditions no actually destructive action can take place in the retina.

It should be pointed out that the injury of the retina by ultra violet radiation is dependent upon the concentration or surface density of radiation incident upon that tissue. Sources of extremely high intrinsic brilliancy are, therefore, more dangerous than extended surfaces, and the possibility of injury can be eliminated by the use of diffusion screens which merely decrease the energy density incident upon the retina without in any way changing its quality. The use of diffusion screens in the case of such sources as the magnetic arc and others of similar character is therefore very desirable as a means of insuring safety.

In sunlight at the earth's surface but a very small amount of radiation of wavelength shorter than 305 $\mu\mu$ is found. Under average conditions radiation of this quality constitutes about 25% of the total radiation. Under normal conditions this is not of sufficient intensity to cause any injury. However, when the eyes are exposed to snow fields illuminated by brilliant sunlight this radiation may be of sufficient intensity to cause snow blindness, which is due to an actual injury to the retinal tissue. We may conclude that with the light sources used in the illumination of motion picture studios there is very little danger of injury to the retina if ordinary precautions such as the use of diffusing screens and glass globes are taken.

As previously stated, wavelengths shorter than 305 $\mu\mu$ are almost completely absorbed by the cornea and crystalline lens, and due to this absorption comparatively serious temporary injuries may

resulting from the radiation within the region of 305 $\mu\mu$ to 400 $\mu\mu$ that recovery is complete and that no permanent injury to these tissues results. The energy density required for this type of injury is very high and with proper precautions no danger should exist from the use of any commercial illuminants in the motion picture studio. Further, it has been definitely established that in order to injure the cornea, iris, or crystalline lens by thermic effects due to the action of infra red radiation, a concentration of energy is required which can only be obtained under extreme conditions.

Commercial illuminants are found to be entirely free from danger under ordinary conditions. The glass enclosing globes used with these illuminants are of such a nature as to reduce the injurious radiation to below the danger point. It would seem from the results of the most recent investigations that the injurious effects of ultra violet radiation have been greatly exaggerated. No injurious effects resulting from the radiation within the region of 305*uu* to 400*uu* have been definitely observed. It would seem therefore that there is little danger of serious permanent injury to the eyes of persons working under any of the commonly used artificial illuminants.

It is very definitely established, however, that certain illumination conditions produce unnecessary strain, fatigue and discomfort. These effects may be produced by the use of intensities and contrasts too great to be taken care of by the accommodation processes of the eye. In order to avoid such conditions, the characteristics of the eye and its response to excitation should be carefully studied. The detemination of the fundamental characteristics of the eye has been given careful attention and many papers dealing with the subject have appeared in the technical literature in the past few years. Among the most important of these may be mentioned those by Nutting[12], Blanchard[13], Reeves[14], and Ferree and Rand[15].

The eye operates over a tremendously wide range of intensity, this range being approximately 1 to 10 billion. The most efficient range of operation is between the brightness level represented by the average daylight and well lighted interiors at night. Its efficiency falls off quite rapidly for brightnesses exceeding 1 lambert and slowly for brightnesses less than 1 ml. The eye can also withstand rather severe overloads for short periods. For instance, an observer can look at a snow field having a brightness of approximately 20 lamberts for some time although continued exposures for such brightnesses will eventually cause temporary blindness. The sensitivity functions of the retina which are of importance in determining efficiency and visual comfort are represented graphically in Figure 12. These curves as indicated represent the sensibility of the eye to glare, contrast, and brightness.

Since the eye automatically changes its sensibility as the intensity of the stimulus changes, it is necessary in specifying any of these factors to state the condition of the eye at the time when these sensibilities are measured. The eye can be brought to a condition of equilibrium by subjecting it to the action of a field of uniform brightness and of sufficient size to fill practically the entire visual

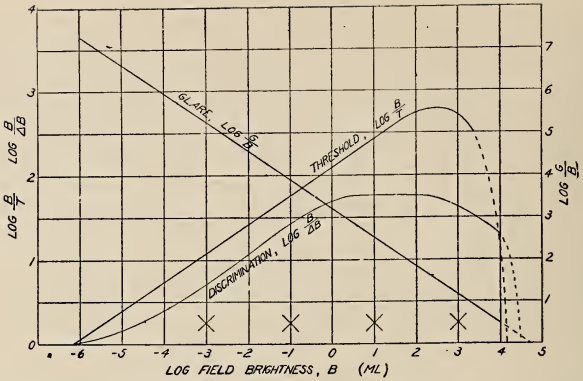

Fig. 12—Glare, Threshold, and Distrimination Functions of the Retina.

field. If sufficient time is allowed for the eye to reach equilibrium, the brightness of this field may be taken as a specification of the condition of the eye as regards sensibility. The eye is then said to be adapted to this brightness level and the numerical specification of the brightness is termed the adaptation level.

The abscissae values in Figure 11 are in terms of this adaptation level and hence for any adaptation level the curves in Figure 11 permit the determination of the brightness which is just uncomfortable (glare), the brightness which is just perceptible (threshold) and the brightness difference which is just perceptible (discrimination). For the sake of convenience the adaptation level values are plotted as logarithms of the actual numbers. The data from which these curves are plotted are given in Table 9. Referring to this figure it will be noted that for an adaptation level (field brightness) of 100 ml. a brightness of 7.25 lamberts is required to produce glare. Under such conditions any light source or reflecting or diffusing material having a brightness of more than 7 lamberts would produce noticeable discomfort. This brightness in terms of brightness per square centimeter is equivalent to about 2.2 candles per square centimeter which is far below the intrinsic brilliancy of the light sources used in modern illumination. It is evident, therefore, that practically any unscreened source will constitute a glare if allowed to come within the field of vision. The prevention of glare and the resultant discomfort therefore necessitate the use of some type of diffusing screen between the source and the observer. It should be noted that the visual sensibility are expressed in terms of adaptation levels based on adaptation to a field uniformly illuminated. Now, under practical conditions the visual field is not of uniform brightness and hence the data available are not immediately applicable. However, they may be taken as indicative of the conditions which will result in noticeable visual discomfort.

It should be pointed out that the elimination of glare in the motion picture studios is of great importance. While no definite pathological effects have been found owing to the action of radiation upon the retina, it is undoubtedly true that long continued ex-

posure to extremely high intensities and contrast produce serious fatigue which may in time result in permanent injury. Moreover, from the standpoint of good acting, glare is undoubtedly extremely undesirable for it cannot be expected that an actor can register the desired emotions when in a state of extreme visual discomfort. No definite data are available relative to the adaptation level of the eye of an observer adapted to motion picture studio conditions. It is highly improbable that this adaptation level is greater than 10 lamberts corresponding to which is found a glare value of 21 lamberts. On this assumption no area having a brightness of 30 lamberts should be tolerated in the field of view. This corresponds to approximately 10 candles per square centimeter, which is again far below the intrinsic brilliancy of the majority of light sources.

While the instantaneous glare threshold is a convenient practical method of determining glare, it does not cover the field entirely. A given source of illumination may not cause immediate discomfort nor be judged glaring, but if a person continued to work under the conditions the result could well be a diminishing of visual acuity and possibly a serious injury. An extreme example of this is exposure to a rather bright snow field where a person does not realize the danger until too late. On the other hand, a source of illumination may cause rather severe immediate ocular discomfort but soon come within the range of comfortable vision after a short period of retinal adaptation. A common example of this is when one turns on the room lights in a dark room in which one has been for some time so that the eyes are adapted to darkness. The relation between the various phases of the glare problem have not as yet been solved although it is a very desirable bit of knowledge.

Glare in any form diminishes the ability to see clearly and is a serious cause of eye strain. Glare from lighting sources can usually be avoided by placing the source high, by concealing the source as in indirect or semi-indirect illumination or by using diffusing globes over the emitting source. As the sensibility of the retina depends upon the total light striking the retina and not merely upon the light striking the center of the eye any non-uniformity between the peripheral and foveal illumination tends to visual discomfort with the extreme of non-uniformity producing glare. When all brightnesses in the field of view are nearly uniform, we find the maximum retinal sensibility and within the working range of the eye glare cannot exist if the field viewed is nearly uniform. Vision remains comfortable with rather high contrasts in the field but is best when contrasts are about ten to one. When the contrast becomes too high we have glare and when a glare spot subtends a small solid angle visual discomfort is most pronounced. Next to the brightness of the glare spot and its angular size, its position relative to the axis of vision is the important factor. The log of the depression of the foveal sensibility shows a straight line relation to the angle between the axis of vision and the position of the spot.

There may be two extremes in problems of illumination; first to tolerate any system that does not cause permanent injury, and

second to reject any system which causes even the slightest ocular discomfort. While it is not necessary to relieve the eyes from all strain, it would be well to aim for much better conditions for the present as well as striving to avoid future troubles from new sources and lighting combinations. The eye is capable of withstanding some overload but should not be abused.

If all precautions concerning glare from emitting sources be observed, we would still find that all objects in the field of view could be considered as virtual light sources. All the polished or glazed surfaces may reflect enough of the light received to become sources of glare and should either be eliminated or properly cared for.

Where intense illumination and undesirable contrast are judged to be absolutely necessary for certain effects much of the eye strain could be avoided by eliminating the strong lights during rehearsal and using them only when actually recording the scene. This would not only relieve the eyes but also would be a saving in illumination expense.

The harmful effects of improper illumination show themselves in interference with ocular functions though in practically no case recorded has there been any structural changes either temporary or permanent. As in the case of harmful radiation there is usually a latent period before the discomfort appears. The first experience seems to be that of having sand in the eyes, then comes a sharp pain and finally a pain in the entire eyeball which may spread to surrounding parts of the face. In cases of instantaneous glare the discomfort is probably caused by the strain on the ciliary muscle in contracting the pupil. In fact much of the eye troubles may be assigned to fatigue of some or all of the ocular muscles. Many people should wear glasses but do not realize the fact. Certain defects are emphasized by certain illumination conditions and eye troubles in the motion picture industry may well be due to the personal eye defects rather than to faulty illumination conditions.

From the standpoint of vision that illumination is efficient which permits the eye to function with the least strain and effort as good lighting allows good seeing. The comfort of out-of-doors daylight illumination should be a standard and while it is not always necessary nor expedient it is possible to obtain a suitable proportion of direct and indirect light. In all cases the eyes should be considered and the physical laws involved should at least be supplemented by psychophysics.

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Discussion

The Chairman: Gentlemen, you have heard this interesting and really remarkable paper by Dr. Jones. Our Society is fortunate in having it. It takes the work of the studio out of the field of experiment and puts it on a really scientific basis, and there should be in the future a great saving of film and a lot of light by enabling us to determine accurately and scientifically the proper light and proper exposure. The paper is now open for general discussion.

Dr. Mott: This most excellent paper has now brought us very complete information on the question of light at the source and in relation to energy and its application in the photographic plate. In this regard the light that I am most familiar with, the arcs, it might be interesting to point out how the values will vary with different currents. It is a fact that we use the plain arc and the other arc at currents going from ten amperes up to 150 amperes, and that the photographic efficiency for equal candlepower changes very greatly in different amperage. Different lighting always changes greatly at different amperage. Therefore, it might be well to have some simple arrangement, so that you can predict what you can get.. (Demonstrates by means of diagram on blackboard.)

Now, Mr. Jones in his most interesting paper pointed out that the relation between the sunlight and the photographic light of a white flame arc was 2.50 as against 100 for sunlight, or 257 for the white flame arc. That was for an arc of 25 amperes with resistance series on direct current.

Mr. Jones: That is in terms of visual efficiency units.

Dr. Mott: Yes, 2.57 for the white flame arc and 100 for sunlight, this white flame arc when taken at 25 amperes on direct current with resistance series.

Now, let us see what happens when you change it to twin arc and alternating current—the twin arc with resisting currents. Now, if we make a two-arc lamp out of it then we increase our power in the two arc and with the same power in the line, this efficiency will jump 50 per cent in the amount of light in proportion to the power taken from the line. If you take this twin arc and put in a series of reactants you can get the same power double light to do what you got in the first case.

Now, we will go one step more. We get two arcs here. Now, we said over here that the light increases with the square of the current. Now, if we take the power in these two arcs, put them in one, doubling the current, it will get up to C^2, four times as much light. Therefore, we will again double our efficiency. So we will go back to the single arc. Now, with a transformer with a ratio of 2 to 1 and reactant control and our efficiency up to 100.

This has been realized commercially in the Wagonhurst lamp,

and this remains to be realized in a commercial way, but there are no fundamental difficulties, as Mr. Howard has pointed out.

Mr. Jones: Mr. Chairman, I wish to point out that Dr. Mott has changed from a visual evaluation comparison to a comparison on the energy basis; the efficiency of the white flame arc in terms of equal energy is 52%. Now, it seems to me that he has gone over over from the 2.57% which is in terms of equal candle power (visual) to a further comparison of efficiency on the basis of equal energy and I cannot quite follow his reasoning.

Dr. Mott: We have the value of this in terms of your determination. Now, the thing that we are interested in is how much light we can get for a given amount of power, and inasmuch as you have taken this as a standard for reference, why it is just as well to point out that for equal horse power we can go to those other stops, and of course, actinicity would probably remain about the same—probably would jump a little bit; but this includes the change in photographic light that you will get when taking the same line power in these cases.

Mr. Jones: But it is not fair to start with a 257% which is based on the visual comparison and then take the 150% and the 400% of that which are based on energy considerations. There is undoubtedly a relation existing between these values but as far as I can see it is not know to us at the present time. We should either make all of our comparisons on a basis of equal candle power or on the basis of equal energy.

Dr. Mott: That is with the efficiency of a 25-ampere white flame arc which was about 10,000 beam candlepower, or roughly, 4,000 candlepower, without a reflector.

Mr. Palmer: I would like to ask Dr. Jones—he spoke about the sensitiveness of the emulsion. Is there in practical production of negative film—is there any very great difference in sensitiveness of diffrent emulsions as they come out?

Mr. Jones: There is certainly some variation although I do not think we would call it a large variation.

Mr. Palmer: What per cent?

Mr. Jones: I do not know definitely just what the variation is but would estimate it to be of the order of +25%. In order to answer this question intelligently, it would be necessary to make speed tests of every batch of film coated over a considerable period of time and then to determine the mean deviation from the mean value. In the laboratory we have not made such a series of tests. Many tests on various coatings have been made but not systematically enough to give a definite answer to Mr. Palmer's question. Judging from our more or less limited number of tests and from our practical experience, I would say that something like 25% is approximately correct. In practical work a variation in exposure of 15% is just perceptible. It will be seen therefore, that the variation in the product is not much greater than a just perceptible speed difference.

Dr. Hitchies: Twenty-five or thirty per cent, you can never tell anything about it. Only one thing—if your speed ran 200 H.D. and

you run it to 300, you know very little about it in the camera; but if, say, you drop to 100, then you will notice it. But 50 per cent you would hardly know in practice.

Mr. Jones: Do you know, Mr. Crabtree, what would be the answer to that question as to variation in speed in the product?

Mr. Crabtree: I think something like what you say—25 per cent is of no moment at all in practice.

Mr. Palmer: You said the emulsion could cause a variation in intensity or brightness of one to a hundred. Have you any measurements of actual studio sets to give us an idea of what the variation in brightness is from the deepest shadow to the white make-up, for instance, on the face of the actor?

Mr. Jones: We have no actual measurements as to the contrast in the motion picture studio work. Some measurements made in a professional portrait studio indicate that rarely is a contrast of more than 1 to 50 encountered.

Black velvet reflects about 2% and white paper or white linen not over 88%. So if contrast is due entirely to differences in reflecting power 1 to 44 will be the limit obtainable. However, since contrast is due partially to variation in illumination higher values than this may be found. In landscape work we have made a large number of measurements and the maximum contrast encountered was 1 to 500. This was a very exceptional subject consisting of a dense woods in which there was a very heavy shadow and with a sky containing a white cloud illuminated by brilliant sunlight. On a gray day contrasts as low as 1 to 8 or even 1 to 4 may be found. I should say that in landscape work an average value would be of the order of 1 to 50.

Mr. Palmer: I think it is very easy to get 1 to 250—very easy in a studio, because they are concentrating spot light and high intensity sources right on the person and neglecting shadows altogether.

Mr. Jones: That is true, but we have no information at all on motion picture studio sets.

Dr. Mott: What effect does change in spectral distribution of energy have on the latitude and halation?

Dr. Jones: Halation is much greater for red light than for blue light. By exposing to light of short wavelengths, halation may be completely eliminated. In general latitude it is greatest for a wave length of maximum sensibility.

Mr. Crabtree: I think it is a little longer than that.

Mr. Jones: I think not. If the exposure is made to blue light for which the opacity of the emulsion is very high the latent image is confined very largely to the surface layers. The effective thickness of the emulsion is therefore reduced and this has a tendency to reduce the latitude of the material.

Mr. Palmer: Supposing that there are thin spots in the picture, where the emulsion is very thin—which light would be the better for preventing, say, retouching of portraiture?

Mr. Jones: If the defects mentioned by Mr. Palmer are actually due to thin places in the emulsion, it is probable that by using monochromatic light of short wavelength the image can be confined more or less completely to surface layers and therefore the variations due to the thickness of the emulsion eliminated to a certain extent. However, good photographic materials are very carefully inspected for variations in thickness of coating before they are sent out from the factory and such defects should be found.

Actinic Measurements in the Exposing and Printing of Motion Picture Film

By W. E. Story, Jr.

THe present paper consists of the chief notes on two branches of photometry as yet unfinished, for which it would seem there might be a use in motion picture work. These two uses of the photoelectric cell have been carried as far as it seems at present advisable, unless some of those more versed in the practical manipulation of films can share the author's optimism.

(1) *Exposing Film.*

In connection with some other work the photoelectric cell was illuminated with various colored lights, and the galvanometer readings compared with the density of plates exposed to the same lights. The reciprocals of the deflections were so nearly proportional to the transmissions of the developed plates that the following experiments were made.

A tube of brass 1¼ inches in diameter and about 20 inches long, closed at one end, had mounted in it near the closed end a photoelectric cell, as shown diagrammatically in Figure 1.

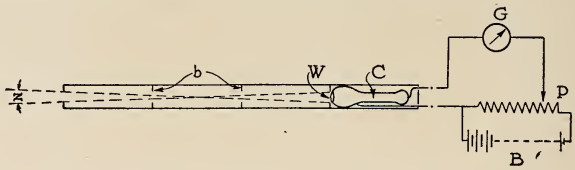

Fig. 1—Diagrammatic Sketch of Telactimeter.

The light entering the cell window (W) is obviously that coming only from objects within the cone N—the baffle plates (b) effectively preventing any appreciable reflection from the tube walls. The dimensions are such that a 6-inch disc will fill the cone at a distance of 10 feet from the open end of the tube. This little instrument we may call a "Telactimeter." The electrical connections are as shown. G is a portable galvanometer, B a battery of dry cells and P a potentiometer. By using a lamp under constant potential as a standard of illumination at a known distance from W, the sensitivity of the apparatus can be maintained uniform from one day to the next by changing the potential across the cell.

Against a black background there were hung seven pieces of cardboard—one painted red, one orange, one yellow, one green, one blue, one violet or purple, and one white. Of these the white seemed brightest to the eye and the yellow almost as bright. A photograph of these was then made on a Seed-30 plate. A print from this plate is shown in Figure 2. As might be expected, the red and orange are quite dark, the yellow lighter, and so on up to the blue,

which appears a little lighter than the white, due probably to some imperceptible yellow tinge in the latter.

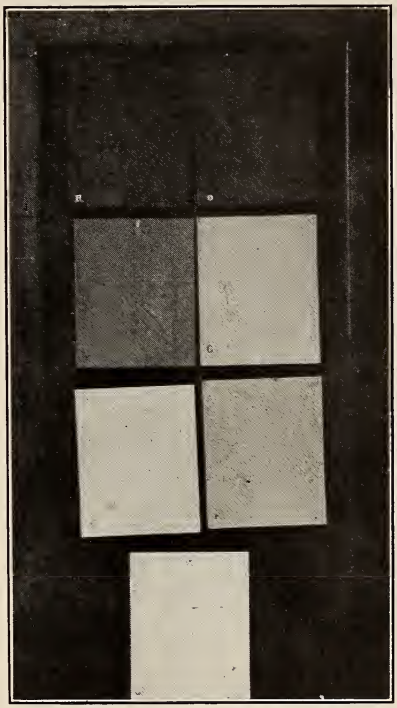

Figure 2

The telactimeter was pointed at each color in turn and the reciprocal of the galvanometer reading then multiplied by a constant determined by the relative sensitivity of the telactimeter and the camera. The product thus obtained was used as the time of exposure for this color, the other colors being meanwhile removed. Of course, if lights of different colors affect the telactimeter and the plate proportionally for all colors, the seven cardboards exposed successively as described, should give equal densities on the plates. Figure 3 shows how very nearly this is true.

From this experiment it was considered that the cell and the Seed-30 plate responded approximately proportionally to change of wavelength, and that the telactimeter might be used for determining the time necessary for proper exposure; or would indicate the average density any particular part of the object large enough to cover the cone, as mentioned above, would have on the developed plate. Whereas the ordinary actinometer measures the light at the camera or the light falling on the object, taking no account of its absorption coefficient, the telactimeter measures the actinic power of the light from the object, regardless of the color of the object or of the light falling upon it.

This apparatus has been tried out with motion picture film and

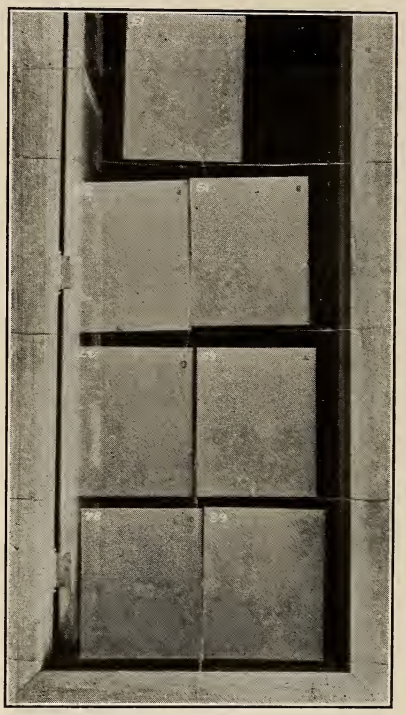

Figure 3

the deflections obtained are proportional to the effect of the light on the film within the limits of the error of the crude apparatus so far available.

It would seem as if there should be a field for such an apparatus. At present each scene is examined through a glass having the proper spectrum absorption curve to convert visual radiation to that which will effect the film. Though such a method would indicate relative contrast on the finished film, the time of exposure would be a matter of judgment, and this is effected so materially by the surroundings and the condition of the observer, as to be at times quite inaccurate. This inaccuracy is of course greatest under abnormal conditions, such as when photographing a small dark object on a large light background or vice versa, or when trying to match the illumination in a studio with that out of doors.

The apparatus has been set up here for the inspection of those interested. Unfortunately the illumination in this room is so far below that of the studio, that objects indoors at a distance from the windows will hardly give a readable deflection. Perhaps, however, some idea of the operation may be obtained by pointing the telactimeter toward objects of various degrees of brilliancy outdoors.

(2) *Printing Film.*

Since motion pictures were first produced there have been

printed many miles of film, without the discovery of any method of determining the time of printing other than those depending entirely on the personal judging by the printer of each scene used—and this in spite of the recognized objections to such methods.

It may be of help in formulating, if not in solving the problem, to approach it from the point of view of one entirely unfamiliar with motion picture practice. Such is the only excuse the author has for the present note.

The one absolute essential for a print is that detail necessary for the understanding of the picture must be present on the screen. Obviously this detail cannot appear on the screen unless corresponding detail exists in the positive film.

Now detail exists in a picture only through contrast, and, in the case of monochromes, through density contrast. It is true that detail depends also on contrast gradient, that is, on the width of the strip through which one density fades into another, as well as upon the difference in the two densities. The width of this strip depends, however, on the sharpness of the negative. With this the present discussion has nothing to do; it deals simply with the printing of a given negative.

The first step in the solution of the problem is, then, to have sufficient contrast in the necessary parts of the picture. By "necessary" is meant those parts necessary for the understanding of the picture.

Whether or not the contrast will be sufficient, will depend, apart from the contrast of the negative, on the slope of the characteristic curve of the positive film. Since this slope is a maximum at one point and but slightly less than this through a considerable range[1] (the so-called "region of correct exposure"), falling off then more rapidly to zero for exposures below and above this region, the positive must for maximum contrast be printed such a length of time that every part of interest has an exposure in or near this region. If there is sufficient contrast in a particular area of the negative, the time of printing may depart considerably from that of the region of correct exposure for this area. If there is but slight contrast, then any under- or over-exposure may lessen the contrast beyond the limit of eye sensitivity. If the contrast in the negative is too low, satisfactory detail will be impossible for any exposure, unless in some way the slope of the characteristic curve can be increased. Knowing the characteristic curve of the positive film the latitude of exposure for the necessary contrast of each part of the film can then be determined, and those exposures which all parts have in common, represent the latitude of the whole picture.

That the time of exposure shall lie within these limits is a necessity; but for the great majority of films there is a wide range of exposure that satisfies this condition. Are there any other conditions it is desirable to fulfill?

So far the physical or objective contrast alone of the screen picture has been considered. The subjective or apparent contrast is naturally that of most interest. This depends not only upon the physical contrast but also upon the actual quantity of illumination.

If this illumination is of too low a value, the physical contrast would not seem as great as it would if more light entered the eye.([2]) In other words, unless there is sufficient light on the screen, full benefit of the physical contrast will not be obtained. Accordingly since the light on the screen is proportional to the transmission factor of the film, if the source and optical system are not such as to put sufficient light on the screen through a film printed to maximum contrast, then a decrease in density will perhaps give a greater apparent contrast though a smaller physical one. Though too much light decreases the apparent contrast also, this condition is so rare in motion picture projection as to be of little interest.

Eye-strain would probably be reduced to a minimum if the eyes were required to change their adaptation level as little as possible. The eye-strain is often quite noticeable when a change is made from a dark title to a light picture, such as a cartoon, and becomes really painful when in the midst of a dark scene the film breaks. The continual adjustment of eye sensitivity necessary with films as printed at present, would be done away with if every film had the same average transmission. Titles at present transmit far less light than the majority of scenes. They are printed dark to give great contrast between the white letters and the black ground. It is a question as to whether the ease of reading thus obtained is not more than neutralized by the effort to adjust the eyes for the change in illumination. The illusion of darkness and blinding light are desirable at times to obtain "effects," and the sudden transition to a lower or higher level of illumination could probably be made far more marked if all scenes, in which it was not desired to call attention to the change in illumination, were printed the same average density.

Still another thing that should be considered in timing the exposure of positive film is that the projection apparatus of theatres is supposedly arranged to give satisfactory illumination with the average run of film as now printed. Any wide departure of future standard densities from the present average film density may involve a hardship to some theatres—probably only to those having at present a low screen illumination.

These considerations would make it seem advisable to have some universal means of determining the time of exposing positive film that would enable each laboratory to expose its film according to some definite rule of density. If then all laboratories adopted the same rule and the same numerical values, each theatre could arrange its projection and general illumination to get the maximum clearness and minimum eye strain for all pictures, thus contributing materially to the comfort of its audience.

To find out, if possible, about what such a rule for printing might be, twenty strips of positive prints from as many different negatives were obtained from a prominent motion picture laboratory. Each strip consisted of a number of sections, each section having a different time of exposure. The section having what was regarded by the expert judge as the "correct" exposure, was marked with a

TABLE 1

No.	Subject	Proprtion Clear Film	Deflection by whole frame: Too Light	Deflection by whole frame: Correct	Deflection by whole frame: Too Dark	Deflection by 1/16″ circle, Too Light: LP	Too Light: DP	Too Light: √LPxPD	Correct: LP	Correct: DP	Correct: √LPxPD	Too Dark: LP	Too Dark: DP	Too Dark: √LPxPD
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
..	No film .	...	...	175.	...	...	...	...	7.0	...	...	...	...	...
..	Clear film .	1.	...	...	...	...	...	...	5.40	...	...	...	...	...
2	Figure . .	.7	106.	85.	63.	4.15	.45	1.37	3.85	.35	1.15	3.25	.25	.90
4	Boat . .	.8	121.	80.	44.	2.85	.35	1.	1.85	.30	.74	1.55	.25	.62
1	Figure .	.5	100.	71.	43.	3.25	1.25	2.02	2.45	1.0	1.57	1.7	.75	1.13
19	Auto . .	.3	83.	68.	47.	...	...	...	...	...	...	...	...	...
6	Figure . .	.2	90.	54.	21.	3.1	.75	1.52	2.5	.60	1.22	1.55	.45	.83
3	" . .	.2	83.	53.	22.	2.8	.85	1.54	2.05	.75	1.24	1.45	.45	.81
7	" . .	.2	63.	41.	26.	3.85	.25	.98	3.25	.20	.81	2.65	.10	.51
15	" . .	.0	76.	40.	19.	3.9	.15	.76	3.15	.12	.61	2.45	.10	.49
9	" . .	.1	57.	38.	22.	4.45	.15	.81	3.85	.10	.62	3.35	.08	.52
11	" . .	.1	62.	35.	22.	5.35	.20	1.03	5.0	.15	.86	4.75	.10	.69
18	" . .	.2	83.	35.	19.	...	...	...	...	...	...	...	...	...
13	" . .	.05	71.	25.	17.	3.05	.65	1.40	2.2	.35	.88	1.55	.25	.62
16	" . .	.2	60.	24.	17.	5.0	.15	.86	4.3	.10	.66	3.35	.05	.41
12	" . .	.1	63.	24.	19.	3.45	.25	.93	3.0	.15	.67	2.0	.12	.49
5	" . .	.0	53.	22.	13.	2.1	.45	.97	1.65	.35	.76	1.15	.25	.54
8	" . .	.1	43.	20.	14.	...	...	...	...	...	...	...	...	...
10	" . .	.1	48.	20.	14.	.95	.45	.65	.45	.35	.39	.35	.15	.23
20	Title .	.	23.	19.	16.	...	...	...	...	...	...	...	...	...
17	Figure . .	.0	26.	18.	12.	2.05	.25	.72	1.95	.20	.62	.95	.15	.38
14	Title .	.	20.	18.	15.	3.85	.25	.98	2.85	.15	.65	2.05	.05	.32

notch in the side of the film. The light passing through these different prints was then measured by allowing the light from a constant source to shine through the film into a photoelectric cell. The galvanometer deflections, very closely proportional to the illumination, are given in the Table. It should be noted, however, that the sensitivity of the cell was lowered for columns IV, V, and VI, in order to read the deflections on the scale.

The films are arranged in the order of total light transmitted for correct exposure, as shown in column V. The measurements of each correctly exposed section are given in columns V, X, XI and XII. A frame differing from this in exposure by two steps lighter was also measured and noted in columns IV, VII, VIII and IX, and by two steps darker in columns VI, XIII, XIV and XV.

Columns VII, X and XIII give the readings when a 1/16 inch opening in a mask was put over the highest light in which detail was desirable; columns VIII, XI and XIV, when over the darkest shadow requiring detail; and columns IX, XII and XV, the square of the product of the two columns immediately preceding each. The geometric rather than the arithmetic mean might be chosen to represent the average light through the film, since contrasts are judged so largely by differences of illumination relative to total illumination rather than by absolute differences. The logarithms of the values in columns IX, XII and XV are then inversely proportional to the arithmetic mean of the densities.

An examination of the table has so far failed to show any method of selection or comparison by which the light transmitted by the different films gives an indication as to the proper time of exposure. Columns IV, V and VI overlap to such extent that the exposure cannot apparently be judged from the total quantity of illumination passing through a frame. Columns VII, X and XIII, and columns VIII, XI and XIV show that there is a great variation in the light passing through the lightest and darkest points of interest. Nor does either the geometric mean of the light (columns IX, XII and XV) or the arithmetic mean (not calculated throughout), show any regularity from which time of printing could be foretold. The subjects give no indication, except that the two consisting of titles allow but little light to pass.

The assumption throughout these tests has been that the so-called "correct" exposure was in reality the most desirable, though it is evident from the readings that some, if not all, of those qualities mentioned above as theoretically advantageous, are lacking.

It is hoped that someone will be able to suggest some means of determining what light can be taken as an indication of the proper length of the exposure under any given condition. With such a determination, the time of printing can be determined very quickly and accurately with the photoelectric cell.

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(1) "The Photographic Rendering of Tone Value," Jones, Jour. Franklin Inst., April, 1920.

(2) "The Fundamental Principles of Good Lighting," Nutting, Jour. Franklin Inst. 183, p. 287, 1917.

Discussion

Mr. Victor: Mr. Chairman, I want to ask Dr. Story if in his experimentation and investigation he has thought of the possibility of furnishing to camera men an instrument equalizing the light in question on his own eyes. For instance, in taking pictures myself—which I do in an amateur way—if I take an interior, I usually over-expose my picture. If I take an exterior in sunlight, I usually under-expose.

I am wondering if any instrument could be put over your eye, spectacles, or otherwise, that would tone down the sunlight so that you would get really a more proper impression as you look through the focusing tube. This really has nothing to do with your theory here, but it occurred to me that such a thing would be a help.

Dr. Story: Of course, by the use of filters over such a device you can change it from a measure of the actinic effect of light to an approximate measure of the visual effect, but I am afraid that this device would not be satisfactory, as the use of a yellow filter would cut down the sensitivity of the cell enormously.

I might just say that a possible explanation of the effect of which Mr. Victor speaks in the over-exposure of the interiors, is that when you are in a room, your eyes wander around all the time; you look through the window and then at darker objects, and your eyes adapt themselves to more light than that coming from the object which you are photographing. In other words, the object looks darker than it would if you looked at it alone, just as the window looks brighter. If this is the right explanation there should be a tendency to under expose scenes taken through windows from inside the room.

Mr. Jenkins: This is very interesting, and I hope the Doctor will find the time to follow it up a little. But there is this phenomena which I would like to have additional information on—if it happens that anybody in the room has it, and I thought perhaps Dr. Jones had made up some rules or tables which we might get. It is this, that in winter time the camera man has to give a little extra allowance perhaps for cold weather. That is the way we put it down there for the pictures we make. In other words, the ratio between our customary opening for a full time exposure, and the appearance through the focusing device in the summer time has a different relation than it does in the winter time. Now, I have always said to the young men who operate the camera for me, "You must remember that that is cold film and it isn't going to act as fast as it does in the summer, that is, when it is warmer." Is there any foundation for that statement? But we do it actually in practice, perhaps it has come about more by a sort of intuitive belief than otherwise. We had no foundation for it. So if we could have that published in our Transactions some time, it would be one of the papers which

would be useful; and the Papers Committee has been requesting me, as all of you, for suggestions; now, there is a suggestion for your new Papers Committee, Mr. President, that a paper on that point would be useful. In the winter time we make different from the summer the ratio between the apparent brightness as we see it through the finder, and the actual photographic brightness, let us say, actinic quality, through the lens in its final result. The ratio is a little different in the summer than it is in the winter; and as I say, I attribute it to the difference in temperature under which we are working. So if we could have a paper on that point, it would certainly be important.

Mr. Jones: I should like to ask Dr. Story if he has determined the spectral sensitivity of the photo-electric cell which he used. In attempting to determine the exposure for printing the positive, he speaks as if an attempt was made to use the straight line portion of the positive material. This is not done in practical work since it is desirable to have the highest light of the picture represented by practically clear film in the finished positive. Such procedure makes it necessary to use the underexposure region and a part of the straight line portion of the positive material. It can be shown from consideration of tone reproduction that better quality is obtained when using the underexposure portions of the positive material, by also using the part of the underexposure region of the negative material. So in practice the underexposure portions of both the negative and positive materials are used. Consideration of these facts will probably modify to a certain extent Dr. Story's conclusions as to the proper exposure in making the positives.

We have made a large number of measurements on the mean transmission of cinematograph negatives and find the variation larger than indicated in Dr. Story's work. We found a variation from 3¼ to 40%. Since it is a fairly general rule in practice to represent the highest light of the picture by a just perceptible density, it seems that the most logical way of determining the exposure in making the positive is to measure the highest density in the photograph which it is desired to reproduce in the positive, this being known it is perfectly simple to compute the necessary exposure.

In regard to the point raised by Mr. Jenkins, the temperature coefficient of photographic sensitivity is not large although it does exist. I do not believe that change of speed with temperature is great enough to account for the effects cited by Mr. Jenkins. I think it more probable that the explanation lies in the change of quality in the sunlight with the seasons. For instance, in the winter when the altitude of the sun is much less than in summer, the light is less "blue" than in the summer when the sun is higher. Assuming then that exposure is judged from the visual illumination, the photographic intensity will be less in winter than in summer even though the visual illuminations are equal. In other words, we may say that the photographic efficiency of winter sunlight is less than that of summer sunlight.

Mr. Story: In answer to Dr. Jones's question—we have not

made any measurements of the actual spectral sensitivity of the cell. Such measurements can be found in the literature of the subject.

Dr. Jones: What kind of cell was used?

Dr. Story: The potassium hydride cell. We feel this is rather play; we don't care to go into it more elaborately if there is no use for such a device. I did not mean to imply that we advocate the use only of the straight line portion of the curve. I merely want to point out that this device will tell us on what part of the curve we are working, be it the straight part or the toe.

The Need for Improvement in Present Practice as Regards Film Reels

By F. H. Richardson.

THERE is perhaps no other one thing in the entire mechanics of the industry which has added a heavier burden in overhead expense than has the film reel, that term as here used meaning the reel or spool upon which film is ordinarily carried.

It is also a fact that the flimsy, cheap, poorly constructed reels of the past have damaged film to an extent which has caused constant injury to screen results in tens of thousands of theatres in this and other countries.

I have myself stood beside the manager of a film exchange supplying dozens of theatres, and we have both watched the winding of a new roll of film just received from the producer on a flimsy, rickety, bent up, decrepit reel, which in the process of a single winding of the film would cause more damage to the same than would cover the cost of a fairly good new reel, and this, too, without a word of criticism or protest on the part of the aforesaid manager.

It is but a statement of fact, no matter how unpalatable, to say that the reels in general use for many years, and a goodly proportion of the reels in use right now, constitute an indictment against the common sense of the industry. They cause very great damage, and thus add a load of absolutely unnecessary expense to the overhead of the industry, all of which must, in the end, in one way or another, be borne by theatre box office receipts, because in the last analysis there is no other source of sustaining income in the industry; hence all its expenses, no matter what kind they may be, must be paid out of that source of income.

Some of the Faults.

The faults both of the old style film reel and of a goodly proportion of the reel now in use, are many. In the first place, while projector take-ups have been vastly improved, the fact still remains that unless the projector take-up device maintains an absolutely steady pull amounting to not more than the maximum pull necessary to rewind all the film, the small-hub reel will, in the very nature of things, cause more or less injury (more or less according to the efficiency of the projector take-up in providing an equal pull throughout the reel) to the first fifty or one hundred feet of film, in addition to which the small hub does not offer anything like an adequate support or stiffening to the sides of the reel.

Aside from injury to the first part of the film under conditions where the projector take-up pull is not equalized, the old small diameter hub cannot, in my judgment, offer that support to the sides of a thousand foot reel which is necessary to keep the sides true and parallel with each other, even though the sides of the reel be of

heavy metal and heavily embossed. If the reel be designed to carry two thousand feet of film, the diameter of the hub should, in my judgment, in no case be less than five inches, and six inches would not be too large.

In considering this matter, let us get the facts fixed clearly in mind. The only thing upon which we must depend for protection of the film while it is handled in the exchange, and in the projection room, is the reel, which also must be, to some extent, depended upon for protection to the film in the process of shipment.

In many exchanges reels loaded with valuable films are subjected to amazingly rough treatment. I have myself watched reels loaded with film taken from the shipping case by exchange employees and literally thrown, or tossed, a distance of fully six feet to a board-top table. If the reel side or sides be dented or bent in the process of such treatment, then the film will inevitably be subjected to more or less abrasion in the process of its winding on or off that particular reel as long as the reel lasts, by reason of the fact that the metal is stretched because it is almost impossible to put a reel back into perfect condition once its sides have been bent.

It requires no particular reasoning power to understand the fact that a reel side supported by a hub of small diameter will be bent out of true very much more easily than will one supported by a hub of considerable diameter. The mechanics of this is too simple and too obvious to require extended supporting argument.

Sides of Reels.

The sides of most of the reels of the past have represented something very close to an outrage on common sense. I have myself seen reel sides the opening in which were punched out by a stamping machine which did not make a clean cut, but left sharp points of metal sticking out from the edges of the holes. These were, for some reason or other, invariably on the inside of the reel, and amazing as it seems, the manufacturer had not ripped them off, nor had the exchange, the films of which were to be carried on those reels. These little points of metal acted very much the same as would minute knife points. They cut the edges of the film, or abraided it, shamefully, and the absurd part of it was that in many instances a film exchange manager has demanded damage from a theatre for the cutting and abraiding of film cause by this particular fault in reels which the exchange itself had purchased and wound its film on. Almost any experienced projectionist can tell you of having received reels of this kind in days gone by.

As a general proposition the sides of reels have been, and still are made of metal of insufficient weight or thickness, and of poor quality. I have myself received film wound on reels of such flimsy character that I have been able to bend metal of the side of the reel over with my thumb and fingers.

The injury cause by a reeel which has been bent, dented and warped out of shape is very great in any event, but is greatly added to by the fact that a large percentage of rewinders found in ex-

changes and projection rooms are out of line, meaning by this that the two elements of the rewinder are so set that the reels are not in line with each other in the process of rewinding.

It is very difficult to estimate the amount of actual damage done by poor reels, but when we consider that the equivalent of about 120,000 thousand foot reel of film is in daily use in the theatres of the United States and Canada and that this film may be conservatively valued at about $20.00 per reel, or 120,000 x 20 = $2,400,000, we see that even so little as one half of one per cent of damage amounts to 2,400,000 x .005 = $12,000.00.

I do not believe any man with comprehensive knowledge of the subject will seriously question the proposition that one half of one per cent of damage is done to film by the poorly constructed reels now in general use, and their resultant utterly wretched condition.

STANDARD REELS

In the following, let it be clearly understood that I am expressing my own individual view only as to what the standard reel should consist of. Frankly, I have not given the matter that close study and minute scrutiny which the adoption of an acceptable standard would call for. The opinion expressed is, however, based on observation which has covered the handling of film, under all conditions, for many years.

In the first place, the reel hub diameter should, in my judgment, be not less than four inches for a thousand foot reel, and not less than five inches for a reel designed to carry two thousand feet of film, these measurements being minimum only. In the case of the two thousand foot reel, I believe a six-inch reel hub would be none too large, because it would add enough additional stiffness and rigidity to the reel sides to more than justify the additional cost and space required in projector magazines and in shipping cases.

The method of attaching the film to the hub I do not care to discuss at this time. There are several very acceptable methods now in general use.

As to the sides of the reels, they should be made either of spring steel wire, properly braced and welded, or of sheet metal of good quality and of sufficient thickness to be capable of withstanding a reasonably heavy blow without injury.

The reel sides should be heavily embossed, the embossing to include a ring clear around the outer edge, and not more than a half inch therefrom.

I am not, and do not pretend to be a competent designer in matters of this kind. All I care to say is that the embossing should be such as will thoroughly stiffen the side of the reel in every way, or perhaps I might say so stiffen it that it will not yield to any pressure it is likely to be called upon to withstand.

What we need is a reel with a large hub, the sides of which will remain true, and equidistant from each other at all points when subjected to such rough treatment as reels must encounter in ordinary

practice. The added cost of such reels would be more than compensated for by the reduction in film damage.

May I respectfully suggest to the Society the appointment of a committee to prepare specifications suitable for adoption by this body, covering the dimensions of and the general counstruction of a standard film reel of one thousand and two thousand foot capacity.

Discussion

Mr. Jenkins: Mr. President, it just so happens that Mr. Richardson and I do not always agree in our conclusions, but I want to say that I heartily endorse his bringing this subject to our attention at this time. The reels are bad that are sent out with film—for I use them in my own home very frequently, borrowing, or buying, or renting the film from the various enchanges in Washington—and the reels are awful; the flanges are often so loose on the hub, or they wabble about so badly that the flanges cut the film; and it tears in two and the show is stopped until the film can be threaded into the machine again; or the reel as a whole wabbles so badly that the sides catch and stop rewinding, with a like break in the continuity of the show. So that it is more than just the destruction of the film; it is the embarrassment that comes from breaking up one's show. The best reels I have in my laboratory are those old fashioned kind punched out of finished steel plate. Those are the reels on which my highly prized films are wound and kept.

The spools should be larger; no doubt about it. It would help the rewinding problem also, and this would lengthen the rental life of the film, as well as continue shows that are stopped by reason of starting with loose-flanged reels, loose because of a small diameter hub. I am heartily in favor of any activities which we can put forward to improve film reels. It is so self-evident that the conditions which maintain today are abominable, that it seems almost unnecessary to mention it. I assume that a great many of you know just what those conditions are just as I have noted them; and I cannot use too forcible language on this very point—that one of the great financial drains on our industry today is that abominable practice of using reels which are no good whatever, and they do it right along with the very nicest sort of film, the most valuable pictures, and it is too bad.

Mr. Victor: Mr. Chairman, I certainly agree with both Mr. Richardson and Mr. Jenkins as to the great need of a better quality of reels. But frankly I doubt whether our adoption of a reel with a large core for the 1,000-foot film would ever be used, because, if I am right in my information, the theatres have reels of their own and rewind the film as it comes from the exchanges on those 1,000-foot reels. Therefore, the reels that the exchanges supply to the theatres are merely used to ship the film on, so to speak.

When you come to the actual use of the thousand-foot reel or spool, it is used with the portable type of machine. Now, I don't know of a single portable type machine being provided to take a larger reel than the present 1,000-foot reel with a small core. If you increase the core, which I admit should be done, your reel becomes much larger and there would not be any equipment to take these reels. I don't see how you can possibly put it over.

Another thing is that no matter what we do, what we standardize, manufacturers of reels are competing with each other in the matter of price. I know a case myself, in my Chicago office. I understood one day that they could buy a certain reel for, oh, perhaps, 28 cents, but one of the boys came in very excitedly and said he had found one at 21 cents, and they decided to buy them without seeing a sample. I think that is the practice in the industry to simply buy a reel at the lowest quotation. But the great objection I see to the possible adoption of a different thousand-foot reel than we have at present is that there would be no equipment to fit it where it is used.

Mr. Jenkins: Mr. President, Mr. Victor's question was more or less addressed to me, and that is my excuse for answering. Mr. Victor has simply forgotten his mathematics just now. The film which would lie on a present sized hub, of a 1000-foot reel, when wound on a four-inch hub does not increase the diameter of ten-inch reel flanges quite one-quarter of an inch, so I am not ready to agree with him that the mechanism for rewinding machines would have to be changed in any way. But I think Mr. Victor's remarks have confirmed the very thing I say—that the film as it comes from the exchange is often on such an abominable reel that it has to be wound by the operator on reels of his own before he projects them. But is that very rewinding that helps to destory the film; it is not just the use of the film in the machine that is bad for the film. The size of the reel, with a four-inch hub, I am quite sure Mr. Victor will discover as soon as he begins mentally to calculate this thing, is not materially increased; that is, increased beyond the permissible clearance in any of the standard machines that I happen to know about—meaning by standard the usual machines.

Mr. Victor: There is a gentleman here from Bell & Howell—I think they make reels—I would like to know the exact size of the reel after they use this larger hub.

Mr. McNabb: We built a large sized reel about nine years ago, five-inch hub with flanges 11 inches in diameter, and it was quite a success at that time. It was a substantial reel and not of the flimsy type that has been spoken of by one of the previous speakers. Three or four years ago we disposed of it to another manufacturer, and I don't know what became of it, that is, whether it is being made or since discarded. However, I want to say that the five-inch hub was a decided success from the standpoint of conserving the film, but there was one objection which I believe was developed afterwards, that is, it took up too much room for storage.

I would like to agree with Mr. Jenkins' last remark that the four-inch hub will take up a thousand-foot roll on the present reel of ten-inch capacity without materially increasing the size of the film rolls; it would probably increase the size a quarter of an inch, I think.

Dr. Story: I should like to ask if that one-quarter inch would interfere with any of the mechanism now in use.

Mr. McNabb: No, I don't think so.

Protection of Inventions

By Thomas Howard.

IN the past six years, thousands of patent applications and patents have passed under my observation. It has been my experience during this time that applications for the new inventions, in nine case out of ten, are prosecuted so poorly that the fundamental principle of the invention is lost sight of in fifty per cent of the cases and has been given to the public, the inventor losing all right to the product of his brain as the result of this.

Engineers and others who devote their thoughts to experimental research evolving new ideas to assist and develop industry should have all the protection to which they are entitled. As a general rule, when the inventor makes up his mind to file an application for patent, he looks around for a patent attorney to file the application. Next, the inventor writes out a description of the invention and hands it to the attorney. If the inventor is unable to pay a large sum, he is charged the regulation advertised price, which is between $70 to $100. The reparation of the case is then turned over to a specification writer, who probably receives $25 to $40 per week as his salary. The case having been prepared, is duly filed and later an action is received from the Patent Office, citing references. These are turned over to the specification writer, who casually glances over the references and rather than spend time and study to draw up briefs which should suggest allowance of broad claims, makes an amendment cancelling the claims and substituting a single limited claim which the attorney declares to be readily on the applicant's structure and thus allowable, and then requests the examiner to pass the case to allowance.

The inventor absolutely relies upon his attorney, believing that he will get the same service the attorney gives to his clients who are able to pay from $200 to $500 for a case.

In examining cases during the last month, the following instance came under my observation:

A Mr. J. Stourm has invented an egg carrier made of two resilient arms which held the egg suspended between its two ends, leaving the sides free. It is a well known fact that an egg suspended at each end is difficult to break, while the side shells could be very easily cracked.

He then suspended these resilient arms by means of a split sleeve which frictionally gripped a rod passed through the split sleeve. This frictional means allowed the shipper to put from one to twelve eggs on each rod.

The requirements of the Patent Office make it necessary to show at least one practical method and therefore the inventor showed in his drawings a corrugated box having a detached cover, the rods bent

on each end so that they could fill in the corrugation and be kept in position by the cover. The attorney in making his claims, concentrated his effort on the corrugated box and the down turned ends of the rod. This inventor would unquestionably have given his invention to the public, but due to our vigilance his case was reissued and he received amongst others a claim as follows:

"An egg carrier, comprising a bar and a resilient member, having a central split sleeve, slidably engaging the bar."

Another case is a tractor which allowed the frame to be in perfect horizontal alignment, notwithstanding the hillyness of the country over which it was trasversing, in other words, this tractor would do its work where one wheel would be lower and the other wheel on the side of the hill or both wheels might be level. The attorney obtained 19 claims, but in examining all these claims I found that any manufacturer could, without permission from the inventor, manufacture an identical tractor. In examining the file which contained 22 references cited, it was seen that all of these pertained to features of the invention which the inventor did not claim as his but the fundamental principle, which was the adjusted means to keep the wheels on grade, had never been patented nor was any attempt made by the Examiner to show such a device in the prior art.

There was at stake a sum of $750,000—quite a sum! By a reissue, the inventor obtained 55 claims which covered his invention thoroughly and completely and fully protected the inventor, and fortunately he was able to protect himself.

A patent is granted for seventeen years and gives a monopoly to the owner. If the claims are limited whereby some individual or corporation can make slight changes enabling them to manufacture without direct permission from the inventor, you can therefore under the circumstances see that no man will invest in such an invention and pay the asking prices, which may be $1,000 or $100,000. This state of affairs makes the inventor skeptical. A patent is not real protection. It is merely permission to take the infringer into court.

Inventor or his assignee must realize that to successfully prosecute an infringement, he must have a good case. Otherwise, he starts out under a handicap with a losing proposition and must ultimately fail, after having expended considerable money.

Here again, the attorney who prosecuted the application for patent may take advantage of the inventor by leading the man to believe that he has a substantial case when he really has not, in order to justify his own shortcomings.

Many an inventor himself is the cause of limiting his own rights by insisting that every piece that goes into the construction of his mechanism should be fully set forth in the claims, believing that he has cut off all loopholes against the infringer, when as a matter of fact, he should insist upon having his claims broad that they will bring out the state of the art, specifying broad means to do the various operations.

Considering the inventions already patented as the state of the art, the proper way of prosecuting a patent is to make the claims so broad that references will be cited on the fundamental principles and thus the inventor will not delude himself as to whether he is really the original inventor with basic or generic rights or not. He will then have knowledge as to his true rights if he has any.

Claims are sometimes limited because the prior art prevents broader claims; in this case, the inventor is prohibited from manufacturing his own invention without permission from the prior patentee, providing, however, that the prior patentee has basic rights. Thus, many an inventor, after having spent money for patents, models, tools, and dies, finds that he has just thrown his money away.

As an instance: An inventor who spent over $35,000 on experimenting on and producing an invention, found that what he had invented and on which he had received a patent, had already been patcured in a broad and basic manner and the patent which was in full force and effect, nullified all his efforts. Thus you can see clearly the reason why a patent application should be drawn up with a view of bringing out the prior state of the art, giving the inventor full knowledge as to where he stands.

A film case was brought to my attention by the inventor who desired to institute infringement suits against producers and exchangers for using a fatty base compound in the cleansing of film.

Several years ago it was discovered that a fatty compound was an ideal cleanser. The discoverer of this fact took the reels as they were received from the exhibitors and passed them through a bath of oil which softened the emulsion and made pliable the celluloid so that when passsed through two rollers having clean cotton which wiped off the oil, took off the dirt and particles imbedded in the emulsion and as the film passed on additional two rollers, also spread out the emulsion sufficiently to fill up the crevices or scratches in the emulsion. The result of this operation was that the film appeared to be new.

In his further experimentation and practice, he found that film which had become brittle due to either climatic conditions or age was made flexible and the emulsion brought to its original condition. Thus, he had found a new way of renovating negative and positive films.

He then applied for a patent and started a business with the result that most all of the manufacturers of film patronized him and he was doing well.

His application for patent was finally acted on and rejected on the ground that it was not new to use a fatty compound or base as a cleanser since the leather industry had been using it and furniture polishes had a fatty base as part of the compound.

An appeal was taken from the primary examiner's decision and before the full board of examiners in chief, after it had been submitted, a decision was rendered, granting to the inventor the right to

have a fatty base patented on the ground that he was the pioneer in the art and the first man as far as the examiner knew to use an emulsion softener for film which would not destroy the qualities of the picture.

The attorney for the applicant then drew up claims and the inventor took out a dozen applications in this and other countries and in each application he used the words "fatty compound plus some other chemicals such as ether, etc.," but in none of the applications did he write a fundamental, basic or generic claim in regard to the fatty substance.

Lately, he found that the entire industry was using fatty means in combination with other elements and then he wanted to bring action for infringement. A study of the case and of all his patents revealed the situation I just outlined. Had the attorney written a claim as follows: "In film cleanser, a compound having a fatty base, into which the film is dipped, substantially as described," it would have given this man exclusive rights and a monopoly.

Now it will be necessary for him or his successors to have his patents reissued at great expense which could easily have been avoided at the time the decision was rendered by the examiners in chief.

A fallacy that has always existed in the mind of the inventor is that an invention must be secretly safe-guarded and not be disclosed to any living soul except his attorney; ofttimes this results in the defeat of the inventor, especially so in suits for infringement. Most inventors believe that the filing of an application or the granting of a patent is like the Rock of Gibraltar and will withstand all attacks. This theory is entirely erroneous. There can only be one inventor and therefore it is not at the time of filing the application for patent, when a man becomes the inventor, but the day that he conceives the idea, which may perhaps be one or two years prior to the filing of his application for patent. In an interference case or in an infringement suit, he will have to prove beyond a question of a doubt that he conceived the idea at a specific time. Now, how can he possibly prove beyond doubt that he did conceive it, unless he has witnesses or such evidence of conception that will convince a court of law or the Commissioner of Patents that he is the *real* inventor, except by describing his invention to some persons of responsibility or by making drawings and specifications and have them sworn to by a notary and then placed in the mail sealed and addressed to himself.

The more witnesses one has of the disclosure of conception, the more firmly can he establish his rights in a case of interference or infringement.

Another unfortunate circumstance which tends to prevent the proper protection of inventions is the short handedness of the Patent Office. Under the present system, there are not sufficient appropriations made to engage first-class, able, competent engineers and patent experts to properly examine and report by actions on ap-

plications submitted to them. Mostly, young men are employed who have no practical experience and are not competent engineers, with the result that many patents are allowed to go through which should have been rejected while other patents that should have been properly protected and give basic rights to the applicant, are either rejected or are the cause of the faulty prosecution of the attorneys by reason of the unsatisfactory examinations and references cited.

Just to give you an idea of what is going on in the Patent Office, on October 5th, 1917, there were 17,941 applications for patents awaiting action. The oldest new application awaiting action was dated September 17th, or nearly one year without any action. On October 1st, 1918, the number of new cases awaiting action had declined to 15,985, practically 2,000 less than in 1917, and the earliest one awaiting action was dated August 21st. This reduction was due to the War period when very few applications were filed. A year later, the number of applications awaiting action jumped 6,000, bringing the total of applications awaiting action to 21,229, and in October, 1920, the number had increased to 38,947. In October of this year, 1921, the total number of applications awaiting action excluding trade mark division was 55,969 or an increase of 17,000 plus trade mark division of 6,829; an awful condition since no application is acted upon except in its numerical order and thus 55,000 inventors are held up, causing a great loss and hardship. This condition must be remedied.

The National Institute of Inventors, and other engineering societies, agitated for the separation of the Patent Office from the Department of the Interior so that fees which exceeded the expenditures and appropriations could be utilized by the Department of Patents for employing able and capable men for the following purposes:

1. To speed up the work of the Patent Office.

2. To reject applications for patents where drawings themselves show impracticability.

In regard to this last statement, I have seen a patent issued on a so-called resilient tire where the spokes work in cylinders on the theory that it will compress the air as each part of the wheel strikes the ground. Simple engineering knowledge will tell anyone that it is impossible for any one of the spokes to move downwardly into the cylinders and compress the air while two or more of the spokes are being held in a fixed position, i. e., when the spokes lie horizontally in a position parallel to the ground.

Some engineering societies have suggested that a board of competent engineers pass upon applications for patents prior to their being filed, but I think this is not right because many inventions claimed to have been impossible have succeeded commercially, despite the objection that they were impractical. Unless the drawings themselves on the face show that the parts cannot work mechanically, then the inventor should continue to use his own judgment as to the filing of the application.

As an engineer, I would like to call to your attention forcibly that there are many unscrupulous advertising patent sellers and promotors, who flood the inventor with luring letters of their ability to sell the invention, which usually ends in the inventor victim advancing a preliminary fee for advertising or for having a commercial prospectus or analysis prepared. These men are sharks who prey upon the inventor and should be shunned; great effort should be made to drive them out of business. Thus, if this Society will consider the separation of the Patent Office from the Department of the Interior, and drive out these patent sellers and promoters, then you will have done a remarkable work.

The motion picture industry, in nearly every angle, is dominated by inventions. It is time, therefore, that we took up the question of patents in its ramifications and aspects, to devise means that will benefit invention, aid the commerce of the United States and preserve our trade prestige abroad. The entire country owes its great financial success here and abroad chiefly to invention and in working out means of further and greater progress, the inventor and his invention must be forgotten.

Now, perhaps I have devoted too much time to condemnation and criticism of the work of attorneys, without offering any constructive advice as to means for remedying the conditions. I shall now briefly sum up, therefore, by offering a few suggestions and a little advice to inventors having ideas requiring protection, a class, by the way, whose interest I have very much at heart:

When you, inventors, first conceive an idea constituting an invention, make a sketch and written description thereof, date and sign these papers before two witnesses of good reputation and swear to them before a Notary Public. Then you will have established a date of conception and will have in your hand a good and valid documentary evidence of invention which may prove of value should a patent subsequently issue and finally reach the courts for adjudication.

Having taken these steps, select an attorney, taking great care in the selection, and have him prepare formal application papers for the patent office, comprising drawings, specifications and claims, covering your invention in its broadest scope. At the time of signing these papers insist upon receiving a full copy of the specifications and drawings for your own use and also stipulate that you be advised as to the progress of the case, insisting upon seeing copies of all official actions and amendments before they are filed.

The first official action, if the specification is properly drawn, should disclose the state of the art to date, as the Patent Office will cite any existing patent that may be thought to conflict with your claim. These citations may or may not be pertinent and, therefore, the inventor should receive from his attorney copies of all references cited, for the purpose of permitting him to carefully compare them with his invention and make suggestions to his attorney. Right

here is where the hard work of the attorney comes in. If he is competent and conscientious, he will carefully go over the case with you, listen to your suggestions and amend and revise the original claims in such manner as to overcome the references and procure for you all the protection that you are entitled to, in the shape of a patent having broad claims that will not conflict with said references, thus procuring for you a patent of commercial value. Be careful that your broad claims are not cancelled on the first rejection, since cancelled claims may eventually work a hardship if the patent, after being allowed, needs reissuing to straighten the monopoly. If by accident, the patent attorney never presented broad claims, the inventor can come back and obtain them. But if the attorney originally presented them and then in order to obtain some sort of patent, cancelled them in response to an erroneous rejection on art, the inventor is precluded from ever obtaining protection. The ruling on reissues should be modified and should be seriously considered.

Since the ordinary inventor would rarely be willing, even if able to pay for it, to take the time that is requisite for exhausted prosecution of an application for patent, the usual course is for the attorney to rewrite the claims in different scope and to accept the patent with such claim as the examiner in routine argument is willing to allow. There should be some means by which the important invention, inadequately protected by the original patent, can be adequately protected by a reissue. During the prosecution of the patent application, instead of cancelling the broad claims the inventor should change a word or two of the claim before rewriting or cancelling the entire claim, particularly if the references cited do not broadly anticipate. The above remarks do not apply to such applications which are clearly anticipated by prior art. Issued patent cannot be considered as "res adjudicata" but the courts have held that unless the errors were made in the prosecution of the application by "inadvertence, accident or mistake," cancelled claims cannot be reconsidered in a reissue.

In the well-known Wicks case (Wicks vs. Stevens, Fed. cases 17616) Justice Bradley rendered the opinion, that if claims covering Stationary Presses had been omitted in the original patent by accident or mistake, the omission could be corrected in the reissued patent. But its application to *presses generally* was first claimed and then cancelled and abandoned in the application for the original patent, and the claims as finally made by the attorney to secure which alone his patent issued, was for a combination applicable to *portable presses* only. It could not be said, therefore, that a neglect to claim the invention to *revolving presses generally* was inadvertence, accident or mistake.

If, however, at any time during the progress of the case you should entertain any doubt as to the interest of purpose or ability of your attorney, the records of the case should be placed in the hands of some competent advisory as a disinterested patent attor-

ney or any reputable association of inventors, whose business it is to protect the interests of the inventors, and who may be competent to advise you as to whether or not your application is being prperly prosecuted.

This course cannot be objected to by a good attorney who knows that he is doing the right kind of work (the other kind do not count) and as two minds are generally better than one, the result should be the issuance of a good and valid patent, readily marketable, of the broadest possible scope, which, in the last instance, is the great disideratum and goal of all inventors.

A few words on secret processes.

I spoke to an inventor who has a secret process for fixing the emulsion on film so that it will not deteriorate if brought into contact with hot or cold water or scratches easily when run through the projecting machine. He claims many other advantages which I will not now discuss, but only in regard to a secret process.

He says that he is afraid to have it patented because he could not control the output of film renovated or treated by his formula. For instance, if his patent issued and became public, then if the Paramount Company ordered twenty prints of Humoresque treated, out of a total of one hundred prints, in what way could he control or recognize the films treated by him or the eighty prints treated and infringed by Paramount?

Of course we all recognize that the element of secrecy must be present and the owner of such secret formula, even when he passes the secret on to his employee or partner, will be protected by injunction by the courts, if such employee or partner use such secret information to start up a business competing with the owner of such secret process. We also know that such secret process can be sold from one party to another and reserve all rights to the purchaser, providing the formula can be reduced to writing and in this instance where a business is of a specialized character and the presence of precaution is necessary to prevent leakage of information, the court may even refuse to require disclosure of it of the character of the secret; this was clearly demonstrated and held in the Eastman Kodak case; in which case the court enjoined Reichenbach from engaging in a competing business in which he could hardly avoid utilizing these secrets in breach of trust.

The inventor, in deciding whether to patent an invention or to keep it secret, must first of all decide whether or not he is willing to lose the right of excluding others from the use of the invention, because of possible difficulty in detecting infringement. If he decides to forfeit the right, he must make the fact of secrecy evident, and must bind to secrecy those to whom he imparts the information to enable them to carry on the work.

The inventor who decides to keep an invention a trade secret for several years and then attempts to patent it will stand no show in court, or in the patent office, against another inventor of a like process, the courts having held that one who designedly and for gain

withholds an invention from public use does not come within the Constitution and Patent Act, for instead of aiding and promoting the progress of science and useful arts he actually impedes it (Kendall vs. Winsor, 21 How 322). So if another inventor files an application for patent, in advance of any application filed by the "trade secret" owner the patent office will not permit the latter to set up a prior date of inception. Keeping an invention a trade secret may lose the patent rights and allow acquisition by another inventor. The courts have held that a patent granted after several years of such secret use was invalid. (Macbeth Evans Glass Co. vs. General Electric Co. 246 Fed. Rep. 695).

A trade secret has only one possible advantage over a patent, that there is no public disclosure; but on the other hand the protection afforded to such a trade secret extends only to those to whom the secret is imparted and creates no right against an independent discoverer who may patent his discovery and thus destroy any rights of the secret user.

As a matter of fact the latter inventor is enabled to acquire superior and dominating rights preventing the user of the secret from manufacturing the formula, and I can go so far as to state that such a patent will invalidate a patent which may be issued to the secret user upon an application filed after an unduly long period of secret use.

Thus in my opinion an inventor should file his application for patent, carry on the prosecution of the application for as long a period as may be possible in the Patent Office, which in some cases may run over four years, and then when the patent is allowed, but before issuance, he can allow the application to lapse and by the payment of $15.00 renewal fee, he can extend the period of secrecy for another eighteen months.

This enables any inventor to acquire the dual rights, first of secrecy over a period of years, and secondly the protection of the Patent Office as against any subsequent independent inventor.

The following is reproduced from a communication issued by the U. S. Patent Offices:

Department of the Interior
United States Patent Office
Washington, D. C.

Patents:

Attention is called to Section 4886, R. S.:

"Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvements thereof, not known or used by others in this country, before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country for more than two years prior to his application, unless the same is proved to have been abandoned, may, upon

payment of the fees required by law, and other due proceeding had, obtain a patent therefor."

This Office cannot respond to inquiries as to whether an alleged invention may be patented, nor make an examination to determine whether a particular invention has been patented, in advance of the filing of a properly prepared application for patent therefor. Such an application comprises a petition, specification, oath, drawing (if the case admits of illustration), and filing fee of $15. Should the application be allowed, a final fee of $20 will be required. A model should not be filed unless required by the Office.

Of the propriety of making an application for patent, the inventor must judge for himself. The records of this Office pertaining to patented inventions are open to public inspection, and may be examined by the inventor or by any attorney or expert whom ties for obtaining patents.

If the inventor wishes to file an application for a patent, he is advised to employ a competent registered patent attorney, inasmuch as the value of patents depends largely upon the skillful preparation of the specification and claims. This Office cannot recommend any particular attorney or firm, but advises applicants to avoid doing business with those who advertise the possession of unusual facilites for obtaining patents.

The Office does not buy and sell inventions. Nor does it publish any lists of "Inventions Wanted." Such lists as are published by attorneys are unauthorized, and so-called "Certificates of Patentability" are not recognized by the Patent Office.

M. H. Coulston, *Chief Clerk.*

Discussion

Mr. Victor: My experience as an inventor and applicant for many patents bears out Mr. Howard's contentions in many respects. I think that patent attorneys differ more in skill than intent. Of two patent attorneys—one may prosecute applications to greater advantage to his client than another, but certainly he is not criminal; his failure to secure adequate protection to his client is not, in all cases criminal. A great deal of the fault is due to the inventor who wants a patent regardless of quality. I myself have a patent attorney who has been employed by me for twelve years. I am well satisfied with his work. He is conscientious and he follows the procedure Mr. Howard has outlined. We sometimes discuss, not other men's inventions, but other inventors. He tells me it is difficult to always secure good patents for all clients because a man who has formed a corporation finds it sometimes necessary to secure a patent and any patent will do, so he tells his attorney to make speed and get something.

I would like to have Mr. Howard's answer to this because I think it is a condition the average patent attorney is confronted with and he is often the victim of a desire on the part of the inventor to get a patent without regard to the quality.

Mr. Howard: In reply to Mr. Victor's remarks, I may say that if I were a patient and I called on a doctor and I suffered from some very peculiar disease and I wanted to be cured, and the doctor said, "Well, Mr. Howard, it will be at least twelve or fourteen treatments before I can cure you"—and I say, "No sir, I want to be cured right this minute and get out of here," it would not be proper for the doctor to say—"Well, Mr. Howard, I will have to do it because you say so." If a thing can't be done under twelve treatments the ethics of a patent attorney should prevent him from misleading any client.

I know several cases where the inventor would make a statement of that kind, but very few and far between. Every inventor desires proper protection and even the most skilled attorney may go off on a wrong angle; he has no one to consult with but the inventor and if the inventor misleads his attorney, his attorney may prosecute a patent which afterwards is found to be valueless. Seventy per cent of the inventions issued today are worthless because of faulty prosecution. There are good and bad attorneys; every attorney would not deliberately prosecute a case faultily.

Mr. Dennington: I would like to ask Mr. Howard one question —the point was not exactly clear to me—in the difference between secret processes, the man who prosecutes a secret process for a period and later might want to seek patent protection but finds some prior application has come in—the difference between that case and where some man in developing a new process or device pursues his development work and yet he has a conception of his invention prop-

erly dated and attested. In one case, I get from Mr. Howard's talk, that the date of conception might govern throughout a later application, while in the case of the secret process it would not—is that the case?

Mr. Howard: No question about the secret process, if you have conceived a secret process in the year 1901 and had used it continually and finally decided to apply for a patent, but in the meantime between the time you apply and date of your conception some later inventor had applied for a patent and obtained it he could positively prevent you manufacturing the formula, notwithstanding you had evidence of conception and proof of goods put out under secret process; it would not avail you. You either have to decide whether you want the secret forever or whether you want your rights protected; you can only have a patent or trade secret. Not utilizing it or non-completion places you in the position of inventor.

Mr. Dennington: But in the case of development work, suppose you are planning to make application for patent as soon as you get some process perfected; you get your date of conception but do not use the process or equipment.

Mr. Howard: Then you are the original inventor providing you have not used it as a trade secret.

Mr. Victor: I think I can assist Mr. Dennington. It's the difference between—not the date of conception and the period of time when you are developing your invention, but a question of when it is placed on the market. If you keep it secret while developing your invention it's different from keeping an invention a secret while carrying on business. All patent applications must state that the article for which a patent is asked must not have been on the market. Am I right or wrong?

Mr. Howard: In trade secrets, a man can have it on the market and later can apply for a patent providing there are no intervening rights, even if it had been in use for over two years.

Mr. Jenkins: If I understand Mr. Howard correctly, then I do not agree with him that a patent can be subsequently reissued and made broader; if there is anything in the Patent Law more distinctly set forth I don't know what it is; a patent cannot be reissued and made broader than it was at first. I have had that happen to me sometimes, but that is on the fundamental, well established rules and not only that, but it's absolute law now. For a number of years past it has been so established that no attorney ever questions it any more, if I understand Mr. Howard correctly, I don't think we should draw that interpretation from his remarks. We are limited as inventors to our first disclosure to the public in the shape of a patent; we are limited to that. Now, the reason for it, of course, very naturally occurs to you. I take Mr. Jones' patent here and say, "Oh, pshaw, if that's all he invented, I can invent and use this particular thing, whether patented or not." The original inventor is limited to his first public disclosure in the way of a patent; that patent cannot be made broader by a reissue. I have in mind one inventor whom you all know, but I won't name him, who had patents

reissued five times. The Court finally took it up and wiped them all out at one shot on the statement that he was limited to what he disclosed in his first patent. You know the man—I see it in your eye.

There are other very interesting questions which Mr. Howard's paper brought to my mind. I might say for Mr. Howard's benefit that I have over 300 patents, American and foreign, so I am speaking from experience; you get your eye teeth cut after a while if you fool with this game long enough. I can go Mr. Victor one better on his attorney. Mr. Wallace Green has been my patent attorney for over 30 years, so there is a comradeship between he and I; we don't play golf together but sometimes we fly together and when we come down we talk about patent matters, but the point that is really essential is we must not be misled by the idea that a patent attorney can get a broader patent by reissue.

Mr. Howard: In reply to Mr. Jenkins, I have not 300 patents of my own but I pass upon 1,000 inventions a month at least and I wish to say that a patent in being reissued can be broadened if by error or mistake the Patent Attorney didn't claim that which he disclosed—the difference between the drawings, specifications and the claims. I read to you today in my paper, several cases passed upon by the Supreme Court where the Court said if the claims had not been drawn specifically to stationary presses, could have been remedied in a reissue, but where the original patent had claims covering presses generally and then the claims were cancelled they could not be allowed by a reissue, so I say any patent can be reissued and there is no patent law on that subject; in the very latest journal issued by the Patent Office Society a very important paper is published in regard to reissuance of patents and cancelling of claims, and it's so fresh in my mind—I have the book with me—so that he can clearly see that inventions can be improved as far as claims are concerned, when you can make any alterations in the drawings.

Testing and Maintaining Photographic Quality of Cinematographic Emulsions

By Alfred B. Hitchins, Ph.D., F.R.P.S., F.R.M.S., F.C.S

THE photographic emulsion is the basis of the moving picture. Two emulsions of course are necessary—the negative and the positive. The negative emulsion must be exceedingly fast, that is to say it must be very sensitive to light; it must be orthochromatic or color-sensitized and be capable of rendering faithfully all the tones of the scene photographed without sacrificing any detail in highlights or shadow, consequently it must have considerable latitude and be an emulsion of comparatively low contrast. The positive emulsion is slow and must be capable of reproducing all that is in the negative, and at the same time must have the possibility of developing to full rich blacks in order to have proper projection value, therefore it is an emulsion of considerably higher contrast than the negative.

A photographic emulsion is made by precipitating silver bromide, silver chloride or silver iodide in a solution of gelatine. The gelatine acts as an emulsifying medium causing the precipitate to be exceedingly fine and uniform so that the emulsion, when mixed, is milklike in appearance. The proportion of silver halides is varied according to the character and quality of the emulsion desired. The exceedingly rapid negative emulsions are usually bromo-iodide; that is, they are silver bromide emulsions with a small proportion of silver iodide. The positive emulsion may be chloro-bromide or in some cases bromo-iodide.

In making emulsions on a manufacturing scale the halide salts of sodium or potassium with the necessary emulsifying gelatine are placed in jacketed kettles, then the silver nitrate is poured into this salt gelatine solution and the silver halide is formed. The temperature at which emulsification takes place and the amount of gelatine present at the time of emulsification are determining factors in quality and character of emulsion. The emulsion is digested for a given time at certain temperatures which have been found to produce the necessary quality. In order to make a uniform product day by day these temperatures must be kept constant and all the mixing, digesting and blending kettles are fitted with recording thermometers. At the end of digestion the final amounts of gelatine are added, the mass is cooled down and then placed in refrigerating rooms and left until it has set to a stiff jelly. This jelly is then put through a machine very much like a big meat chopper, the whole machine being made of silver or pure nickel. The emulsion is cut up into fine worm-like shreds and washed in repeated changes of water in order to free it from the products of chemical reaction and the excess halide salts. When washing is complete the shreds are drained and melted up ready for coating or spreading upon the

celluloid base. Just previous to coating the emulsion is passed through a vacuum filter to remove dirt and other foreign substances, for the emulsion for moving picture work must be free from dust and dirt.

The machines for coating are highly specialized units, each machine being set in a long alley into which only washed and conditioned air can enter; there are means of varying the temperature and controlling the humidity of the air throughout the length of the alley. A coating machine head is shown diagramatically in Fig. 1,

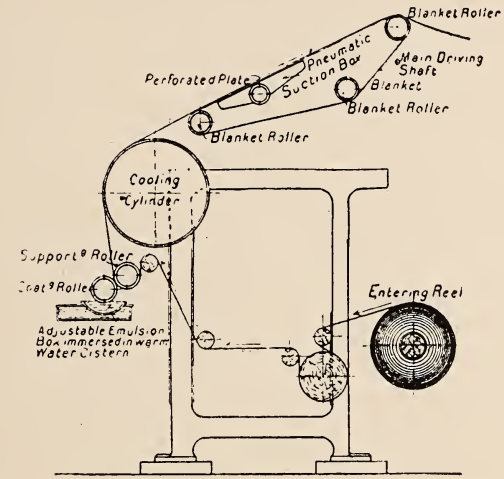


Fig. 1—Diagrammatic Sketch of Coating Machine Head.

the passage of the stock through the machine being plainly shown. The emulsion is held in a water-jacketed pan, and means are provided for maintaining a constant level and is transferred to the celluloid either by dipping or beading. In dipping the celluloid a tension roll comes around, which just touches the surface of the emulsion in the pan. It is transferred by a second beading roll by capillary attraction. After the celluloid has received the emulsion the stock rises over a chill roll and is carried by a suction apron to the first lifting stick, then carried on down the alley in festoons. During its passage down the alley the necessary drying and curing takes place and the stock winds up at the far end of the alley ready for transference to the slitting machines which cut it into motion picture width.

It will be readily understood that a large plant devoted to the production of moving picture film in millions of feet per week must have efficient methods of control in order to produce day by day emulsions of the correct character and quality. Knowing the qualities desirable in negative and positive emulsions, it is obvious that very strict tests must be made of the photographic performance of

these emulsions as regards speed, rate of development, contrast and other emulsion characteristics. This work has become a little science all to itself and is known as sensitometry.

Shortly after the introduction of the gelatine dry plate it was customary to express the speed of an emulsion as X times, meaning that it was X times the speed of a wet collodion plate. Such expressions naturally had very little meaning, as they were based on a variable factor. Early in the days of dry plate photography a well known photographic scientist, Leon Warneke, introduced a sensitometer having a series of numbered squares with increasing quantities of opaque pigment. The plate to be tested was placed in contact with these numbered squares and an exposure made to light emanating from a tablet of luminous paint which had just previously been excited by exposure to burning magnesium ribbon. Upon developing and fixing the test strip the last visible number was taken as expressing the speed of the plate.

The principal objections to this method were that no two numbered plates agreed in density, and the light emitted by the luminous surface varied considerably between its excitation and the exposure of the plate. Also the pigmented squares showed selective spectral absorption. We still see instances of plates marked upon the old Warneke system. For instance, Seed plate "23" and "27." It is here implied that for the same standard exposure these two Seed emulsions would show as the last visible squares Nos. 23 and 27 respectively. Chapman-Jones introduced a modified Warneke sensitometer with a series of twenty-five graduated densities, a series of four colored squares and a strip of neutral grey, all five being of the same luminosity, and a series of four colored squares each passing a definite portion of the spectrum. This tester was used with a standard candle as a light source and is still in use for rough estimations of the speed and color sensitiveness of plates. A number of other methods, more or less similar in principle, were suggested, but none really proved practicable. In 1890 two English scientists, Dr. Hurter and Mr. Driffield, published a paper entitled "Photochemical Investigations" which dealt with the chemical, physical and mathematic principles underlying a scientifie system of testing the speed and other characteristics of photographic emulsions. Since Hurter and Driffield's time a great many investigators have worked on the system, elaborating it and adding to its accuracy.

In connection with the testing of emulsion speed, there are several terms and definitions which must be thoroughly understood. The most important are Opacity, Transparency and Density.

Opacity is the optical property of a substance (in our case silver) to impede the passage through it of light. In other words opacity is the suppression of light or its absorption by the silver image.

Transparency is the inverse of this and is measured by that fraction of the original light which the silver image transmits.

Density is frequently confused with opacity. By Density is meant the number of particles of a substance spread over a given

area. In our case it is the relative quantity of silver deposited per unit area and its symbol is the letter "D."

The relations existing between opacity, transparency and density, and also the terminology generally used in practical sensitometry are shown in Fig. 2. A consideration of these definitions enables us to trace the connection between the densities of a theoretically perfect negative and the light intensities which formed them.

$$O = \frac{\textit{Intensity Incident Light}}{\textit{Intensity Transmitted Light}} = \frac{I}{I}$$

$$T = \frac{\textit{Intensity Transmitted}}{\textit{Intensity Incident}} = \frac{I_t}{I}$$

$$D = -\log_{10} T = \log_{10} O$$

$$I \div O = I_t \text{ or } I \div I_t = O$$

Putting $\frac{I}{I_t}$ into logs gives

$$\log I - \log I_t = \log O = D = \textit{Density}$$

For instance when a plate transmits half the incident light

$$I \div I_t = \textit{Opacity}$$

$$100 \div 50 = 2$$

$$\text{Log } I - I_t \log = \log O = \textit{Density}$$

$$\log 100 = 2.000$$

$$\log 50 = 1.699$$

$$0.301 = D = \textit{Density}$$

I		I_t	T	O	D
100		100	1	1	0
100		10	.1	10	1
100		1	.01	100	2
100		.1	.001	1000	3

$$\log I - D = \log I_t$$

$$\log I_t + D = \log I$$

Fig. 2—Relations between Capacity, Transparency and Density, with Terminology Chart.

Density is a logarithm of the opacity and since in a theoretically perfect negative opacities are directly proportion to the intensities of the light which produced them, it follows that each density must be proportional to the logarithm of the light intensity which produced it, or more correctly density is a linear function of the logarithm of the intensity of light and the time of exposure. So that in a theoretically perfect negative the amounts of silver deposited in the various parts are proportional to the logarithms of the intensi-

ties of light proceeding from the corresponding parts of the original object.

The practice of a system of emulsion speed measuring calls for a good deal of special equipment, the more important instruments are as follows:

1 Some form of standard light for making the exposures.
2 An exposing machine used in connection with the standard light for impressing the tests strips with a series of known exposures.
3 A thermostat for maintaining the developing solutions at constant temperature.
4 A photometer for reading the densities of the strips made in the exposing machine.

Standard Lights—Hurter and Driffield in their original investigation used the English Standard Candle. The principle objection to this light is its spectral composition. Candle light is decidedly orange-red. For non-color sensitive emulsions this may be used, but with yellow or red sensitive emulsions the speed readings would be absolutely wrong. The readings would be five or six times the true speed. The most satisfactory light source is acetylene. special burner giving a long cylindrical flame is used. The burner is surrounded by a circular metal chimney having a small rectangular opening fitted with a cone which extends to within three millimeters of the surface of the flame. Thus only a very small portion of the flame is used, and by keeping the gas pressure and the height of the flame constant the intensity of the light does not vary 1%. The acetylene light is calibrated to a standard candle. In front of the rectangular opening in the chimney a special blue violet filter is placed that reduces the spectral composition of the acetylene to practically the same as daylight.

Exposing Instruments—Numerous instruments for impressing a graduated series of exposures have been proposed and they may be divided into two classes, depending on whether a time or an intensity scale is used. Intensity scales usually consist of a sheet of glass covered with squares of pigmental gelatine, transmitting known amounts of light. Thus, in the Warneke sensitometer previously described, each square transmits one-third less light than the preceding. At the present time intensity scales are very seldom used in practical sensitometry. A time scale may be impressed by intermittent or continuous exposure. For many reasons a continuous or non-intermittent exposure is most to be desired and is always used in the testing of slow emulsions like positive. A time scale impressed by intermittent exposure is easily obtained with a sector wheel having a series of angular openings of the following values:

180 - 90 - 45 - 22.5 - 11.25 - 5.625 - 2.812 - 1.406 and .703 degrees. Each angular openings passes twice as much light as the preceding one and gives double the exposure. The sector wheel is revolved during the exposure in front of and as near as possible to the sensitive film. For negative emulsions it is usual to expose 40 c.m.s.

and as the largest angle on the wheel is 180° we must give an exposure of 80c.m.s to obtain an effective 40 c.m.s The form of the wheel is shown in Fig 3. When the exposures are made with a wheel of this type there is a constant error known as the intermittency error. If an emulsion is given, for instance, a continuous exposure of one second, and upon development yields a certain density, another strip of the same emulsion which has been given a series of intermittent flashes which altogether total one second will,

Fig. 3—Sector Wheel of Sensitometer.

upon development, give very much less density than the one which received the continuous exposure. The continuous exposure brought about a definite light change in the silver bromide emulsion, the intermittent exposure coming in flashes, each flash made very little effect upon the emulsion and there is a tendency for the slightly acted upon silver halide to return to the normal or stable condition, hence the intermittency error is most noticeable through the small angles of the wheel and is least objectionable when measuring very fast emulsions. The error, however, becomes very great on slow emulsions and would be altogther too high for reliable readings of positive film.

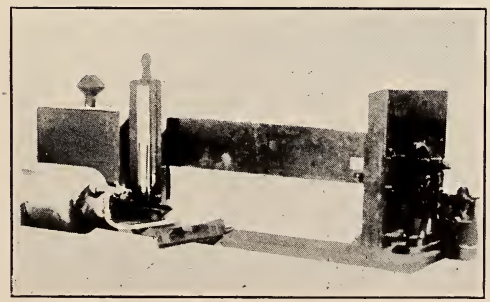


Fig. 4—Sensitometer.

The sector wheel for testing negative emulsions is enclosed in a box 12x12x2 inches. At the back of the box are fitted grooves to carry the film-holder. The complete instrument is shown in Fig. 4. A pulley is provided by means of which the wheel can be rotated during the exposure of the film. A small 1/15th H.P. motor geared down to 50 revolutions a minute is used. A box 6x6x33 inches contains the exposing shutter worked by a milled head. The special acetylene burner is fitted on a stand having a horizontal and vertical movement by rack and pinion so that the light iself may be placed at one meter distance from the film surface and exactly centered. The acetylene tank, manometer and lamp house are also shown in the illustration. The film-holder is arranged to take two strips 4¼-inch x 1 inch. The instrument used for impressing a series of known exposures upon positive emulsion is designed so as to give continuous exposures, thus doing away with the intermittency error. A bed plate two meters long is arranged with a series of rollers set in ball bearings over which a slotted plate is pulled, Fig. 5.

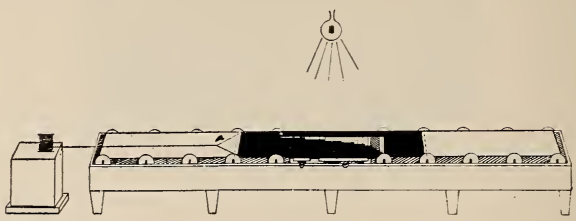


Fig. 5—Arrangement for Continuous Exposure of Film.

The steps are cut in the ratio of powers of the square root of two. The sample of positive to be tested is placed in a film-holder directly under the slotted plate. The plate travels the whole length of the bed, and during its passage gives a continuous exposure to the sample strips. The plate is pulled by a very accurate motor and can be set to traverse the entire length of the bed in 10, 20, 40 or 80 seconds. The light source used for this test is an electric lamp which is very accurately controlled by a semi-automatic device. Two ample holders are provided—one to take one strip 1 inch x 7 inches, the other to take six strips 1 inch x 7 inches, so that a number of samples may be tested at one time, if necessary.

Thermostat—A modified form of the Freas water thermostat has been found very satisfactory for controlling the temperature of developing solutions. The complete installation is shown in Fig. 6. The thermostat tank has a capacity of 340 liters of water and is fitted with a paddle stirring device and a mercury regulator which controls the electric heaters through a thermal relay. Hot point tubes are used for heating. There are devices for maintaining the water at constant level and for quickly cooling the water in the tank when the room temperature is too great. A specially designed top is fitted to the instrument with developing cups set down into the water.

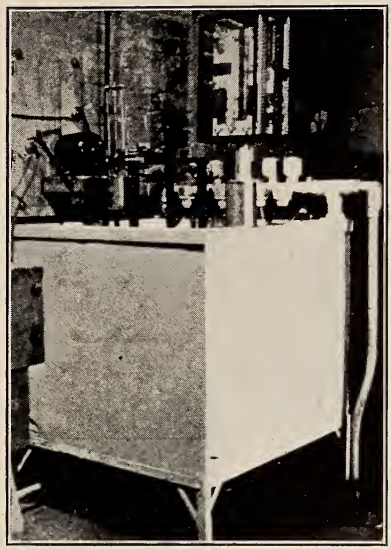


Fig. 6—Water Thermostat used for Controlling of Developing Solutions.

The film strips to be developed are held in small metal slides which fit around the inner periphery of the cylinder entering the cup Within an inner cylinder there is a small multiblade paddle which pulls a steady stream of developer from the bottom of the developing cup and discharges it gently over the top of the cylinder, distributing it evenly over the film strips. Fig. 7 shows this part of the in-

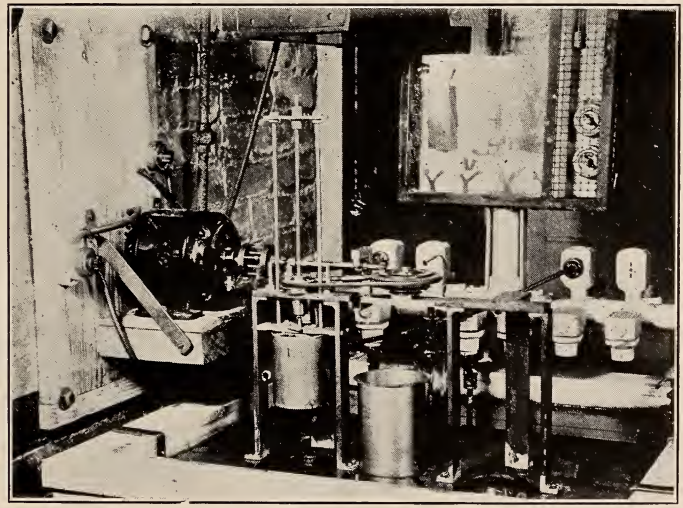


Fig. 7—View of Inside of Water Thermostat.

strument in detail. When the various development times are complete the film strips in their holders are withdrawn and placed in the fixing bath without being handled with the fingers. The accuracy of this thermostat is within 100th of a degree plus or minus, and it will run unattended day in and day out. For accurate results in sensitometry it is of the utmost importance that the temperature of the developer be constant.

Photometers—A photometer as used in photographic work is an instrument for measuring the absorption of light by various media. Polarization or spectro-photometers are usually employed in sensitometric work. The Martens (Fig. 8) polarization photo-

Fig. 8—The Martens Polorization Photometer.

meter is an excellent instrument for the purpose and gives very accurate readings. In this photometer extinction is obtain by means of a Wollaston prism. The formula of converting the readings to densities is log tan $^2O^1$—log tan $^2O^1$ in which O^1 is the angle or degree of rotation with the negative density in position and O the angle without the negative density or in other words the zero of the instrument.

Fig. 9—Appliance of Strips of Film after testing Water Thermostat used for controlling temperature of developing solution.

Whether we are testing negative or positive film the procedure is practically the same, with the exception of the exposing machine and the light source. The film-holder is loaded with two strips of the film to be tested; the strips lie side by side and are exposed together in the exposing machine. After exposure the strips are developed in the thermostat at 65° F. for times t^1 and t^2 in such ratio that $t^2 = 2t^1$. Almost any developer may be adopted as a standard, but potassium bromide must not be added in emulsion-speed testing. The time of development is a matter of convenience. If too short, the densities are thin; and if too long, the higher densities are hard to read. The time of development does not affect the speed readings obtained. After development the strips are plunged in clean hypo and when completely fixed are well washed and immersed in a 5% solution of hydrochloric acid for a few minutes to dissolve any lime salts which may be deposited in the film. The strips are then allowed to dry naturally. The result obtained in shown in Fig. 9. One edge has been left unexposed and is called the "fog strip." From this we can measure the inherent fog in an emulsion viz.: the density of the gelatine, the celluloid and any silver reduced without light action. The series of graduated densities are measured with the photometer, and the results minus fog reading plotted in the form of a curve on a special chart. This curve is known as the characteristic plate curve. The curve is of an S-shape, and if the emulsion has been sufficiently exposed may be divided into three regions, Fig. 10. The concave portion A-B corresponding to underexpos-

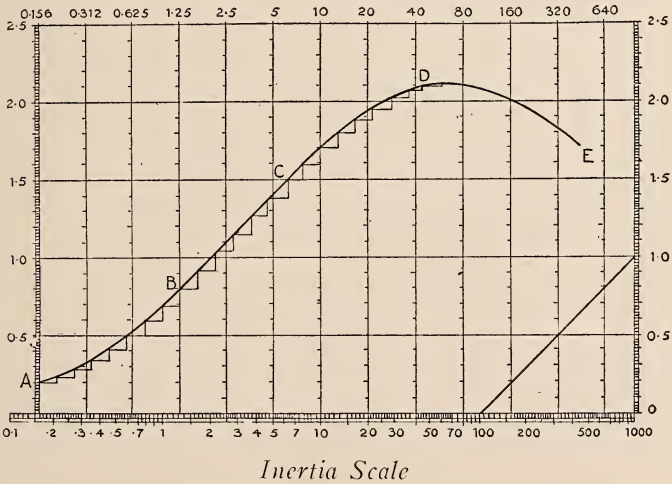
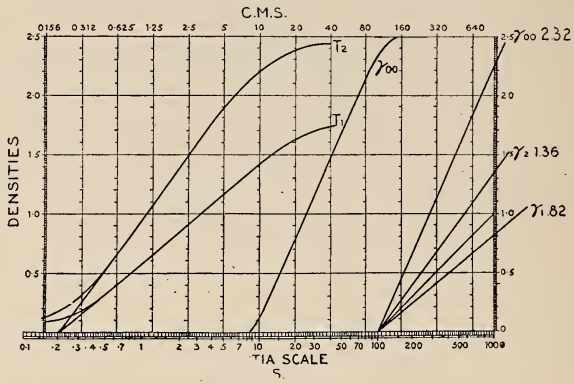


Fig. 10—Characteristic Plate Curve.

ure; the straight-line portion B-C corresponding to correct exposure; the convex part C-D denotes the overexposure period. If we compare this typical curve to a flight of stairs it will be seen that in the underexposure period the steps show a gradually increasing rise. Bearing in mind that each step means growth in density, it will be

seen that we have in this period a false relationship. Proportionality exists between exposure and density instead of between exposure and opacity. A negative, the gradations of which fall within this period, will have strong contrast and be recognized as underexposed by the practical photographer. In the period of correct exposure the steps are of equal rise, that is to say each doubling of the exposure is represented by an equal gain in density, and a negative made within the correct exposure period differs as little as possible from that which at the beginning was defined as theoretically perfect. The definition of a perfect negative was that the densities of the negative should be proportionate to the logarithm of the exposures which produced them, and it is characteristic of the straight-line period of the curve that the densities are proportionate to the logarithms of the exposures, hence the longer the straight-line period the better the rendering power and latitude of an emulsion. The over-exposure period is marked by a gradual decrease in rise of the steps which finally become almost imperceptible. In this period the densities, instead of growing with increase of exposure, steadily decrease. A negative falling within the overexposure period will also give a false rendering, but in an opposite direction to the underexposure period. Underexposed negatives show too much contrast; overexposure yields a flat, thin negative. The chart on which these curves are plotted is shown in Fig. 11. The top line of figures rep-



Inertia Scale

CMS

Fig. 11

resent exposures in candle meter seconds. The figures at the left-hand side represent densities. The bottom line is the inertia scale used in determining the emulsion speeds. The righthand set of ordinates are gammas and represent, in a graphic manner, the actual degree of contrast in the negative. The letter *V* has been adopted as the symbol for contrast. To obtain the speed of an emulsion the straight line portion of the curve is prolonged until it cuts the inertia scale, then 34 ÷ 1 = the speed of the plate. This particular constant, 34, holds good only when the light source is equivalent to a standard candle. In the sample shown the inertia is .2 and the speed 170. Inertia is really a measure of the least exposure which will

just mark the beginning of the straight-line or correct exposure period. The speed of an emulsion is the inverse value. The longer the exposure required to bring a plate to the beginning of the correct exposure period the slower the emulsion. An inertia therefore is really an exposure expressed in candle meter seconds.

In all emulsion speed testing it is essential that two strips of the film be exposed together, then one strip is developed for t^1 and the other for t^2, that is to say one strip is developed twice as long as the other. The two series of densities obtained are read on the photometer and the curves plotted on the same chart. It will be seen that although one strip was developed twice as long as the other the inertiæ coincide, but straight-line portion when prolonged cutting the scale at .2. After we have plotted the t^1 and t^2 curves of any emulsion we can read not only the speed, but can obtain in addition a lot of useful information relating to the character of the emulsion. We can show graphically the amount of contrast that any particular emulsion will give for a given time of development. This is plotted by drawing parallel with the straight line portions of the t^1 and t^2 curves, lines from 100 on the inertia scale until the cut the γ scale. Line t^1 will then give $\gamma 1$, and t^2 will give $\gamma 2$. Supposing the times of development for t^1 and t^2 to have been three and six minutes, then $\gamma 1$ and $\gamma 2$ represent graphically the degree of contrast and density obtained in three and six minutes development. When the γ line of the film coincides with printed γ line of the chart the contrasts of the subject photographed are correctly rendered. If the reading is below 1 the contrasts of the subject are reduced, and if above 1 are increased. From $\gamma 1$ and $\gamma 2$ we can determine $\gamma\infty$. This is an important factor. It measures the ultimate contrast and density obtainable with a given emulsion. $\gamma\infty$ can be determined by direct development. A strip of the film is exposed as usual to a graduated series of light intensities and then developed for 45 minutes, the densities read and the curve plotted. A parallel to the straight-line portion of the curve is drawn from 100 on the inertia scale to the γ scale and where it cuts is taken as $\gamma\infty$. In the example shown, Fig. 11, $\gamma\infty = 2.32$. We can also calculate $\gamma\infty$ mathematically from the figures obtained for $\gamma 1$ and $\gamma 2$. The formula is as follows:

$$\gamma\infty = \frac{\gamma 1^2}{2\gamma 1 - \gamma 2} = \frac{.82^2}{2(.82) - 1.36} = \frac{6724}{2800} = 2.40$$

By direct development we obtain 2.32 for $\gamma\infty$ and 2.40 by calculation.

Another interesting characteristic of emulsions is K or the velocity constant. This is the speed with which an emulsion develops. The formula for this calculation is as follows:

$$K = \tfrac{1}{3} \log_e \frac{\gamma 1}{\gamma 2 - \gamma 1} = \tfrac{1}{3}\, 2.3026 \times \log_{10} \frac{.82}{1.36 - .82}$$

$$K = \tfrac{1}{3}\, 2.3026 \times \log_{10} 1.52 = \tfrac{1}{3}\, 2.3026 \times .1818 = \tfrac{1}{3}\, .43881 = .1463$$

The factor K depends upon the emulsion, the developer and the temperature of the developer. It increases when concentration of the developer is increased and is usually higher in a slow emulsion

than in a fast one, and it decreases as the film ages. For various classes of work it is necessary at times to produce negatives of different contrast. It is a very easy matter to produce a negative of the degree of contrast judged to be the most suitable, for this is simply the control of γ and γ is entirely dependent on time of development for a given emulsion. For portrait work a γ .80 has been found suitable because softness and modeling are important. For architectural work and interiors generally a γ of 1 is suitable, and for landscape or outdoor work a γ of 1.30 has been found best. Know. ing $\gamma 1$ and $\gamma 2$ for a given emulsion the time of development necessary to reach any chosen γ can be shown graphically. The construction is shown in Fig. 12. Here $\gamma 1$ is .82 and $\gamma 2$ 1.36. We use an

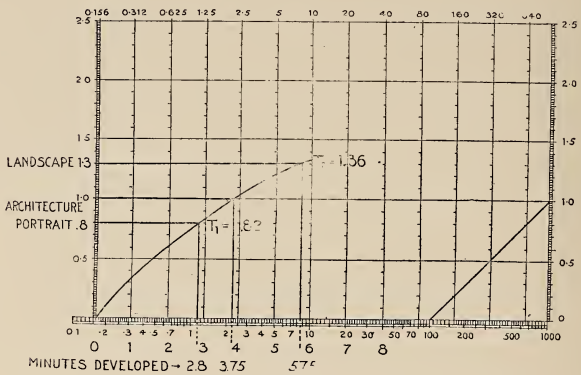


Figure 12

ordinary chart and make the base line division "Minutes of Development," and the left-hand ordinates "Gammas." Then there are three points through which a curve can be drawn O, .82 and 1.36. $\gamma 1$ was obtained with 3 minutes development, and $\gamma 2$ with 6 minutes development, so the density corresponding to $\gamma 1$ is plotted on the 3-minute line, and the density of $\gamma 2$ on the 6-minute line, and the curve drawn. To find the time of development for gammas of .80, 1 and 1.30, horizontal lines are drawn from these points on the lefthand scale, and where they cut the curve a perpendicular is dropped to the base line. In the example shown a γ of .80 is obtained with 2.80 minutes development, $\gamma 1$ in 3.75 minutes and $\gamma 1.30$ in 5.75 minutes development.

When a manufacturer states that his film should be developed for a certain time at a certain temperature, he knows that with the developing formula given a suitable γ or contrast will be obtained, that will give the best average rendering of the object photographed.

Figs. 13 and 14 show typical factory charts of negative and positive film. The negative has a speed of 243, comparatively low contrast, $\gamma 1$ being .36 and $\gamma 2$ being .66 obtained in 2½ and 5 minutes development. $\gamma \infty$ is 1.22. The curves show the quality necessary for a negative emulsion, a long scale capable of faithfully render-

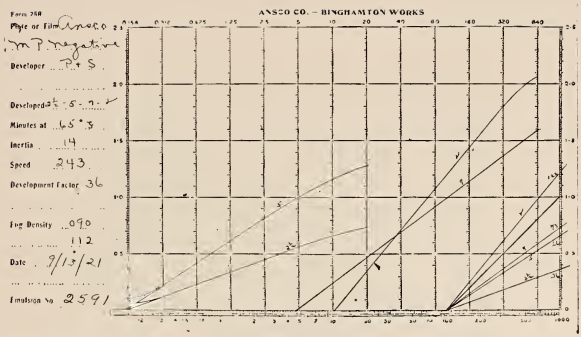


Fig. 13—Typical Factory Chart for Negative Film.

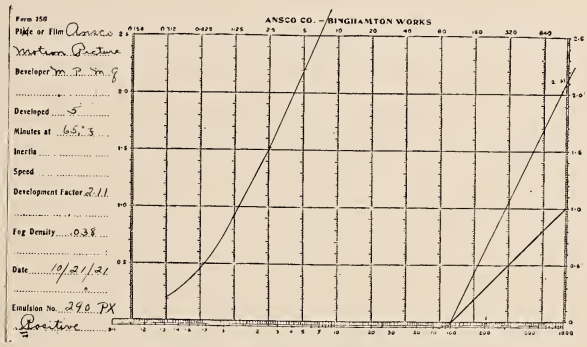


Fig. 14—Typical Factory Chart for Positive Film.

ing a long range of tones and a long straight-line portion indicative of latitude in exposure. The longer the straight line portion the greater the latitude, that is to say greater errors may be made in judging exposure and a good negative still obtained. The positive emulsion shows the degree of contrast necessary for the production of a rich positive of good projection value.

Some other uses for this system of measuring emulsion character are testing of developing solutions, the action of intensifiers or reducers. The various results obtained with different developers, tank solutions, temperature of development or time of development, can be shown graphically, and the instructions issued with the film are arrived at after careful testing in this manner. The photographic value of light sources can be very effectively measured and their relative actinic power plotted.

Apart from the determination of the speed, fog γ_{00} and velocity constant of emulsions, there is another important factor which must be tested. This is the color sensitiveness of negative films. To measure this a Hilger Diffraction-Grating Spectograph is used. This instrument is designed so as to project and bring to a focus in the

image plane a diffraction spectrum much in the same way as the image is brought to a focus on an ordinary camera. The instrument is shown in Fig. 15.

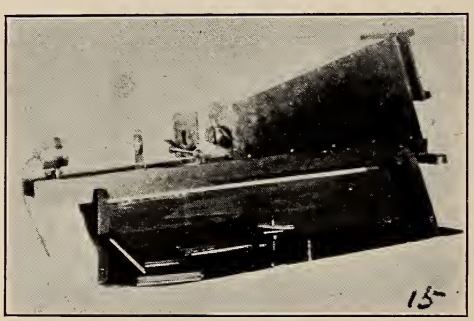


Fig. 15—Hilger Diffraction-Grating Spectrograph.

The film or plateholder is 3¼ x 4¼ inches and has fitted into it an accurately engraved wave length scale. The film to be tested is exposed behind the wave length scale to the action of the spectrum. The spectroscopic slit has in front of it a black glass wedge that produces a gradient of exposure across the width of the spectrum so that we obtain a negative that shows graphically the color sensitiveness curve of the emulsion. This automatic curve plotting is due to the wedge. If an emulsion is very sensitive to a certain color that color will stand more damping down by the wedge, before its power to impress the emulsion is lost, than will a color to which the plate is not so sensitive, and so the maximum or peak of the curve represents the wavelength to which the emulsion is most sensitive. The results obtained are shown in Fig. 16. The first

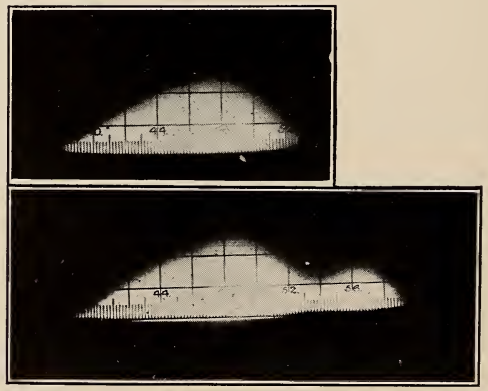


Fig. 16—Spectrograph Curves.

curve shows a non-color sensitive emulsion. Its maximum is at wave-length 4800 in the blue and it is quite insensitive to yellow. The second curve shows an orthochromatic or color-sensitive emulsion such as is used for negative cinematographic film A maximum still exists in the blue, but in addition there is a secondary maximum at 5600 in the yellow-green. This additional color-sensitiveness is obtained by adding a dye—erythrosine—to the emulsion during manufacture. The presence of the dye gives to the emulsion the power of absorbing yellow light instead of passing it, and the light so trapped is used in forming a developable image. The spectrograph is also used for determining the absorption and transmission of the various dyes used in dyeing and tinting positive film.

In addition to the purely scientific tests all batches of emulsion are subjected to a practical factory test which embraces all the usual handling that the films would undergo in the commercial finishing laboratories.

The description of a testing system is rather dry and tiresome, but to the man in the plant it is a living thing—something which indicates in a graphic manner the results of his experiments. From what has been described of the system you will readily understand that the results of any changes in manufacturing methods or experiments can be measured and recorded in black and white. What the variation in the readings mean to the emulsion-maker would entail a thorough discussion of the theory and practice of emulsion-making which, of course, is not possible in a paper of this nature, but without the help of a scientific system of measuring and recording emulsion quality, it would be exceedingly difficult to produce uniform emulsions day by day and still more difficult to carry on experimental work with a view to improving emulsion quality.

The manufacture of photographic materials is one of the most fascinating and at the same time one of the most difficult branches of applied chemistry and physics. There is no other manufacturing process so beset with difficulties, and yet with all its difficulties the work is of absorbing interest, because there is always something to learn and always some difficulty to overcome. The description given of the system of testing and controlling emulsion quality is just an outline, without dwelling in any way upon its intricate physical and mathematical foundation. Testing the quality of the photographic emulsion is just a small part of the work. Efficient testing and control starts with the nitrating of the raw paper stock for the nitrocellulose dope and ends only when the film is placed in the cans for shipping.

The High Intensity Arc Lamp

By A. D. Cameron.

THE remarkable record of engineering progress in the motion picture industry for many years marked little improvement in the light source used for the projection of the completed picture. During that period, the motion picture had passed from an adventure to an industry. Producers had equipped studios to secure unusual photographic and scenic effects. Exhibitors had built theatres which were unrivalled in magnificence. The only notable change in the arc used for projection was a gradual increase in current to satisfy the longer throws, the added house lighting and the general demand of the public for a brighter picture. Arc amperes increased from 35 to even 150 with no compensating development along the lines of greater efficiency in light utilization or in light production.

With the old style projection arc, the increase in current beyond a certain point does not result in proportionate increases in light. High current arcs were difficult to control and projection reached a point where a radical change was necessary if screen intensities were to continue to increase. Efficiency itself could no longer be neglected. Power bills for high current arcs are an item of maintenance sufficiently great to merit attention. The engineering problem, then, was to evolve a light source of higher intensity, which had a higher utilization factor, which consumed less energy per lumen produced and which might bring such added benefits as ease of operation and truer color values.

Fortunately, a development of 1914 pointed a way to this end. In July of that year, Heinrich Beck brought to this country an arc lamp which, for the same current that had heretofore been used, gave from three and a half to four times the amount of light. The principle of the lamp was the employment of uncommonly small electrodes, the positive having a highly mineralized core. In the operation of this lamp, the positive electrode was rotated about its axis and the negative electrode was placed at an angle to the positive in such relation that the negative flame drilled a deep crater into the face of the positive electrode. This crater was filled with the vapor of the minerals of the core and emitted an astonishingly high light flux. This lamp and its derivatives are now known as high intensity lamps, the term "high intensity" covering both the intense light flux and the high current density which results from the employment of the exceedingly small electrodes. The General Electric Company, recognizing the high merits of this lamp, bought the United States patents covering it.

The first application of this lamp was for searchlights and as such, it was used extensively both by Army and Navy during the war. Its industrial application did not come until later. In the

motion picture industry lamps of this principle first appeared in studios for spot, flood and even general lighting. Such a lamp is described in the transactions of the S.M.P.E. for October, 1920.

The five years experience in the operation of high intensity lamps in the searchlight field settled beyond question the practicability of such a device and when the demand came for a more powerful illuminant in the motion picture projection field, it was only necessary to adapt the standard mechanism to meet the new conditions.

The first step was the selection of an appropriate current rating. It was known that the most popular average rating of projection arcs among the better class theatres was 75 amperes. It was decided that lower current might prove helpful and it was conceded that a relatively small percentage of theatres could utilize higher currents. The first model was built, therefore, for an average current consumption of 75 amperes.

Since this was the exact rating of the 24-inch high intensity searchlight, it was known that 11 m.m. carbons produced the maximum effect at this current. Also, the burning rate of both positive and negative carbons was known which established the gear ratios in the automatic feeding mechanism.

The problem then resolved itself into (1) the positioning of the crater with respect to the condensers to obtain the greatest possible utilization of the light produced; (2) the design and arrangement of operating parts to form a simple, reliable mechanism.

In searchlight practice, the horizontal positive carbon faced a mirror which reflected the light back through an opening in the rear of the housing. For projection purposes, it was decided to eliminate the mirror and face the arc directly into the condensers. The positive carbon was in the horizontal plane and the negative at an angle of 60 degrees. The distance from the arc to the condenser was limited to a minimum of 3½ inches to prevent excessive breakage. The 1/50 H.P. motor which was used to revolve the positive carbon was also enabled by an ingenious system of gearing to feed both positive and negative carbons.

Since it was possible to calculate the burning rate of the carbons to a fairly exact degree, it was also possible to select wear ratios which would maintain a constant rate of feed. As an additional precaution, the small motor was connected directly across the arc rather than to an outside source of supply. If the arc length increased the motor speed increased, consequently the rate of feed increased and vice versa. This is not sufficiently accurate in searchlight work where the arc must remain correctly focused with respect to the reflector within 1/64 inch. In motion picture projection, however, the requirements were not so exacting, the periods of operation were shorter and the simplification of operating detail seemed to outweigh the other considerations. No electrical, mechanical or thermostatic focal control devices were inserted. Hand controls were superimposed upon the motor feed so that the arc length could be corrected manually. In actual experience, it has

been proven that no hand adjustments are necessary during the projection of a reel.

The results attained in commercial operation verify the laboratory calculations. The screen intensity is almost exactly twice as great as an old-fashioned arc at the same current. The color more nearly approximates the characteristics of daylight and there is a better color relation in color films and a better definition in black and white prints. From an operating standpoint, the adjustments have been simplified to a point where it is practically automatic. Actual projection experience has dictated the advisability of certain detail changes, particularly in springs and contact point, but no fundamental or inherent defects have occurred.

The high intensity arc lamp opens a new field of engineering development. Its characteristics would seem to make a lamp of this nature more suitable for projection than any other arrangement previously used. Much remains to be accomplished. A lower current rating, perhaps 50 amperes, will be required. A higher rating, perhaps 120 amperes, will find use. Even more powerful arcs will be necessary for studio lighting. Spots, floods and broadsides must produce a spectrum which more closely approximates that of the high intensity arc than any now in use. Unless the light for production and the light for projection are of the same character, there will be distortion. Film tinting may no longer be necessary to correct color deficiencies in projection light sources. Color prints find a new impetus if a true interpretation of their values can be secured. In fact, the entire industry finds a new channel for engineering achievement.

Discussion

Mr. Palmer: Mr. Cameron, you spoke about the fact that you would get better results if you showed the picture with the same kind of carbon as it was taken with; at least, I understood you to say that. Is there anything to that?

Mr. Cameron: I think there is. If you produce a picture, using light sources of a certain spectrum and reproduce it on the screen with a light source giving entirely different color values it would have a decided effect in colored pictures; it would not show up in black and white.

Mr. Bassett: There is one interesting question that I think Mr. Cameron's talk brings up. The high intensity lamp saves a great deal in current; or rather you might say that it gives much more illumination for the same current. In making installation of high intensity lamps, it has been my experience that the exhibitors used the same current that they had been using, and instead of saving current they utilize the advantage to double the screen intensity; so that it is really going more to improvement in projection, rather than to saving in current, or economy. The fact that they do keep their current at the same value that was used in the old arc, brings in the question of carbon costs.

These high intensity carbons cost considerably more than the low intensity, or the ordinary carbons. Because they are running at a high current density means that we have to have them 18 inches in length to give sufficient time of burning. They are slender for their length, which brings manufacturing troubles keeping them straight and so forth.

The carbons originally were used in the Navy and Army searchlights and were made on very rigid specifications. This makes the price of the carbons, as they would have to be furnished to the trade, higher than they should be. Now, the idea ought to be considered that if we could give more latitude to the manufacturer of carbons, and not hold him to such rigid specification as the Navy has required in the past, we might be able to cheapen the carbons. If, however, we let up on the specifications of the carbons, and should use carbons, we will say, with greater variation in diameter, it seems to me that it would bring considerable trouble with the mechanical feed, where the rate of feed is set—carbon variation would necessitate resetting the rate of feed for every carbon.

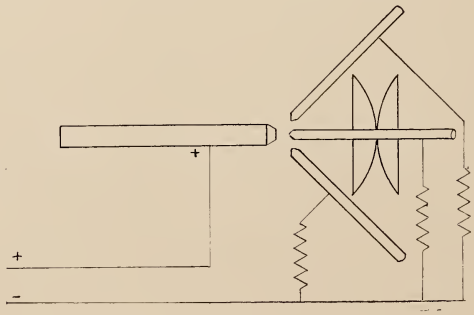
You may recall in my paper at Dayton last year, that I described a high intensity projection lamp that was completely automatic and was built for the purpose of compensating for variation in the rate of carbon consumption. As a high current density, variations in the carbon feed will show up very much more than they will in the old arc, where the consumption was very slow, and for that reason we have found that the automatic is practically necessary to compensate in running even a batch of carbons that is made

in accordance with Navy specifications. Now, if the carbons can be cheapened by letting up on the specifications, will the mechanical control of the type Mr. Cameron has described be sufficiently accurate to be practical?

Mr. Cameron: That is a very interesting point. I imagine the change in specification, or increasing the latitude, would have some effect on the cost of your carbons. Just whether that would be great enough in percentage to prove interesting—it would simplify the manufacture, from the standpoint of the carbon people. Whether it would prove sufficiently economical to make it entirely desirable is a matter still to be determined.

Mr. Jenkins: If I understand Mr. Cameron, the light is not in the flame at all, but is from the little crater practically in the centre of the carbon. It may be of passing interest, and the thought may help out a little in bringing out further points, if with your permission I describe what was used down in the Circle Theatre at Washington for ten months.

A positive carbon (see accompanying sketch) was used placed straight behind the condensers. Now, appreciating what Mr. Cameron has just brought out so nicely, if we could have a single point source of light like this, or as near as possible to that, it would be ideal and at the same time take away all the shadows which negative carbon might cause here that you refer to. I made a lamp with three negative carbons located something in that shape (illustrating) and connected each up through its own separate resistance. The flames bothered somewhat, so we placed the two lower ones slightly lower or slightly out of equi-spaced relation with the top one; they were not exactly 120 degrees apart; the lower ones were a little closer, the reason being that the rising flame would help these two and retard the upper one. These were all put on balancing rheostats, and gave a very pretty spot on the plate and a very white canvas. It is no advantage over what has been described to us, except that it was a home-made arc lamp that does not require a device to rotate the positive carbon; it has actually worked out very nicely. The flames do not come straight in across the gap, but they hug in toward each other, and actually burn a very pretty crater, and the negative carbons create no shadow at all. We got a very nice, clear, sharp picture. As I say, it is simply a home-made idea which has been



so much more admirably worked out in the lamp which Mr. Cameron just explained to us.

This lamp ran for ten months, I think at 27 amperes.

Mr. Cameron: With the same size carbon?

Mr. Jenkins: With the same size carbon. This was, I believe, a 5/8 positive carbon, and the negative carbons, as I remember it, were three 1/4 inch carbons. I tried different sizes to find out which size was best.

Let me first say that that lamp was taken out of the theatre because it was too efficient. Working alongside of the common type of arc lamp in one of the machines and this arc lamp in the other machine, they found it a little bit difficult to make them balance. This gave a better light and a sharper picture, and because they advertised on the outside of their house "the finest picture in the city," they did not like to have that disturbing factor enter into the observer's mind, that here was one picture perhaps a little better than the other picture. That is one of the reasons it was taken out. The other was that I wouldn't maintain it any longer for nothing (laughter). Another advantage is, you can get practically as brilliant and as sharp and as distinct a picture on the screen with A. C. current as you can with D. C. current, because the negative carbons do not have much of a crater on their ends, and do not face the lenses. You can increase them a little and not have any crater, they will hardly be red. Whereas the spot will have an intensity as great as that of the old-fashioned, two-carbon arc, and it does not have the disturbing factor on the canvas that the second spot in the A. C. current gives. So we took it away. But the effect was that of a single positive carbon, having a single crater exactly in the center and in the axis of the condensers, and to operate for the projection pictures, really worked out very nicely.

We did not find that the operator had any difficulty in maintaining them. The three carbons were fed by a sleeve shaft—a solid shaft with two sleeves on it, and there were three controlling handles that lay side by side, so that you could individually move up either of the negative carbons, or grasp them as a unit and turn all four of them off together. It really worked out nicely, considering the experimental make-up, and that was all it was for. But there was a rather interesting thing that came up, and that is that you can light one of those carbons and the others will light themselves presently. The thing is perfectly balanced because it is electrically balanced. If one arc is a little shorter than the other, it will burn more current than the others, until the arc spaces across are uniform, and balances it up.

Mr. J. H. Hertner: In Mr. Cameron's paper he states that the driving motor's connection is across the arc. I would like to ask whether his company considers it better practice to use constant potential source current through a rheostat, or whether they consider it better practice to use a constant current source.

Mr. Cameron: We do not consider that the connection of the motor affects that question at all, because the motor, in the first place, is a 110 volt motor, rated down to 55 volts—that is, the arc operates at 55 volts. If a series machine is started on open circuit that voltage rises to 180 volts—something of that sort. If the carbons are apart and the motor is taking that voltage, the motor itself can stand it for the short period of time necessary to bring the carbons together.

There are two other factors which enter into it. The instructions ordinarily given to operators of series machines are, never to start up from open circuit, but to start up from short circuit. That is, in starting his first arc, he starts his machine on short circuit—the lamps short circuited—he brings the carbons together, opens the switch, and then as the carbons heat up, separate his carbons. So there is not, in the first place, any necessity for the motor ever being operated on open circuit. Even so, the strain on the motor for the few seconds necessary to bring the carbons together and back won't hurt the motor; and further than that, the projection manufacturers who are using the lamp are installing a small snap switch in the motor circuit, so that if anything occurs that the motor generator is open circuited and given higher voltage, the higher voltage is not (applied) until the arc has been started.

Two methods have been tried for using the high intensity and not rotating the carbon. That has been tried first by a magnetic circuit here, which has a blowing effect on this arc and brings it more or less in that shape and leaves the crater practically as it is, without cutting off the upper rim.

And another interesting thing: This scheme has been tried on the high intensity lamp up to 150 amperes, using just two negative carbons, not three, and the lamp I saw operate was rather unsteady.

Mr. Kunzmann: I would like to ask Mr. Cameron if he has the data compiled as to the cost of carbon as against the saving of energy in a high intensity lamp.

Mr. Cameron reads printed data:

	Carbon Cost* Per Hour	Power Cost Per Hour	Total
High Intensity Lamp at 75 amperes.....	$.20	$.156	$.356
Regular Proj. at 120 amperes.....	.125	.318	.443
Regular Proj. at 75 amperes.....	.07	.710	.240

*Based on Oct., 1921, p ices.

Mr. Palmer: Mr. President, speaking about cost. I would like to know how much these 75 ampere lamps cost; that is exclusive of the lamp part—just the units themselves.

Mr. Cameron: I don't believe they are sold that way.

Mr. Palmer: Well, how much does it cost with the lamp part?

Mr. Cameron: I believe the Nicolas Power Company, for instance, sell a complete projection machine, so equipped, for $900 to a theatre; and I believe their standard one, with the old type, sells for $675.

Mr. Kunzmann: It does not cost any more to put the high in-

tensity equipment in than it does the regular carbon arc equipment when comparing high intensity outfit against regular arc lamp equipment and arc control device.

Dr. Jones: Mr. President, I would like to inquire whether on this arc that Mr. Cameron has described there has been any measurement of the intrinsic brilliancy of the crater and also as to the color temperature of the light as a whole. I would like to get some idea as to the color and the intrinsic brilliancy in the crater.

Mr. Cameron: I haven't those measurements off-hand. They were discussed and I think given somewhere, probably in Mr. Bassett's paper at Dayton.

Mr. Manheimer: May I ask Mr. Cameron for the following information regarding carrying capacities in feeders supplying installations where high intensity arcs are used? Basing our assumption on an installation of two high intensity arc machines, what are the instantaneous current values;—when two arcs are in series; when one arc is short circuited and the other lamp is operating alone?

What is the normal operating current required for a D.C. lamp and what for an A. C. lamp and would a present feeder installation suitable for two ordinary arc projectors be suitable for two high intensity arcs?

Mr. Cameron: Assuming a "series" motor generator set the current in all cases would be 75 amperes.

Assuming a "multiple" motor generator set or a direct current power supply with rheostats at each arc the current for one arc will be 75 amperes; for two arcs 150 amperes.

The high intensity arc is not made for operation on A.C. but can be so operated in an emergency by cutting out the motor and feeding the carbons by hand.

Any present installation for 75 ampere arcs will be suitable for high intensity lamps of the same current.

Mr. Manheimer: What capacity would be required in a two-wire feeder supplying two such lamps?

Mr. Cameron: 75 amperes.

Mr. Kunzmann: I would like to ask Mr. Cameron what they have done in developing a 50 ampere lamp.

Mr. Cameron: A test has been made that showed a 50 ampere intensity arc lamp to be the exact light produced by a 100-ampere lamp of the old type.

COMMITTEE REPORTS

Report of Nomenclature Committee

YOUR Committee has worked hard to discover for the words listed the definition which most nearly expresses the idea in the minds of those who use the term, on the assumption that the words used define the thing, function, or act visioned in the minds of authorities in the art.

In an effort to unify the terms used in our own art with those employed elsewhere, the personnel of the Committee was selected from wide sources of employment.

Certainly a definition should apply to the same article when used in different branches of the same art, for example, it would not do to say that an "Objective is the imaging lens on a projecting machine," when, as a matter of fact, an "Objective" is a lens which forms images in a variety of instruments, in our own, as well as in many different arts.

It has been difficult to determine what should be included, and what should be omitted. But after a great deal of discussion, the following were adopted as working rules, namely, that——

(1) The Committee should give to words used in older arts and industries, their previous accepted meaning.

(2) Definitions of words should be selected which define their meaning rather than explain uses.

(3) Definitions should be as short as consistent with unquestionable identification.

(4) Definitions should not be included in the list which are so self-evident or of such wide use as to make our work seem cumbersome and trifling.

And that the following three classes of words only be defined:

(1) Expressions belonging to the projection industry alone, the meaning of which has long been accepted by the whole industry.

(2) Expressions from other industries used universally in motion-picture work, with specialized meanings.

(3) Expressions the meaning of which may be difficult to find in ordinary reference books or which are already used in more than one way in other industries.

Your Committee has been engaged in this work for more than four years now, in a conscientious effort to meet all objections without the destruction of the entire fabric, but so far without very definite result, because it is so easy to criticise and so difficult to constructively amend.

The Committee feels, therefore, that further criticism of a definition should be accompanied by a definition believed by the proponent to be more desirable.

It is obvious that whatever is adopted should be added to from

time to time, and the proposal of terms and their definitions is earnestly solicited.

However, as it is believed unlikely that better definitions than those read and amended in open meeting last May, and printed in the transactions of that (Washington) meeting, and which doubtless all of you have read and considered, the Nomenclature Committee recommends as a beginning that that list be adopted as printed, after the correction of typographical errors.

C. F. JENKINS, *Chairman.*

Motion Picture Nomenclature

Society of Motion Picture Engineers.

Definitions adopted by the Society of Motion Picture Engineers, at its Buffalo, N. Y., meeting, October 31, and Nov. 1, 2 and 3, 1921.

ACTION—The director's signal to the players to begin performing.

ARC—A column of very hot light-emitting gas, carrying an electric current sustaining this condition.

BACK FOCUS—The distance from the principal focus of a lens to its nearest face.

BUSINESS—Action by the player; e. g., business of shutting door.

CAMERA—The director's signal to the photagrapher to begin taking the scene.

CHANGE-OVER—In projection, the act of changing from one projector to another without interrupting the continuity of projection.

CINE—A prefix used in description of the motion picture art or apparatus.

CLOSE-UP—Scene or action taken with the character close to the camera.

CONDENSER—The lens combination which deflects the diverging rays of the luminant into the projection lens.

Collecting Lens—The lens of the condenser nearest the light source.

Converging Lens—The lens nearest the objective.

Center Lens—The lens of a three lens combination, lying between the collecting lens and the converging lens.

CUTTING—Editing a picture by the elimination of unacceptable film.

CUT-BACK—Scenes which are returns to previous action.

CUT-IN—Anything inserted in a scene which breaks its continuity.

DEVELOPING—Making visible the latent image in an exposed film.

DISSOLVE—The gradual transition of one scene into another.

DIRECTOR—The person who superintends the actual production of the motion picture.

DOUBLE EXPOSURE—The exposure of a negative film in a camera twice before development.

DOUBLE PRINTING—The exposure of a sensitive film under two negatives prior to development.

DOUSER—The manually operated door in the projecting machine which intercepts the light before it reaches the film.

DUPE—A negative made from a positive.

EFFECTIVE APERTURE—The largest diameter of a lens available under the conditions considered.

Definitions Submitted by the Nomenclature Committee for Consideration by the Society of Motion Picture Engineers

EQUIVALENT FOCAL LENGTH—The equivalent focal length of a combination of lenses is equal to the focal length of a simple thin lens which will give an image of a distant object of the same size as does the combination lenses.

FILM SIZE—See Special Report of Committee.

FRAMING—Moving a frame into register with the aperture during the period of rest.

LANTERN PICTURE—A still picture projected on the screen by a stereopticon.

LANTERN SLIDE (*Stereo Slide*)—A transparent picture for projection by a stereopticon.

PROJECTOR—A lantern for suitably moving and projecting motion picture film.

RETAKE—A second photograph of a scene.

SPLIT REEL—A reel of film of two (or more) parts, the subject of each part unrelated to the subject of the other part.

Special Report Nomenclature Committee

The Nomenclature Committee recommends, on the following matter, referred to it by motion of this session, that——

The 1⅜ inch film in wide use for so many years shall be known as *Standard Film;* and, that——

The film at present known as safety standard shall be known as 28 *Millimetre Film.*

C. FRANCIS JENKINS. *Chairman.*

The convention adopted this report for action at the next meeting.

EXTERIOR—A scene supposed to be taken out of doors.

FADE-IN—The gradual appearance of the picture from darkness to full screen brilliancy.

FADE-OUT—The gradual disappearance of the screen-picture into blackness. (The reverse of fade-in).

FEATURE—A pictured story a plurality of reels in length.

FILM—The ribbon upon which the series of related picture elements is recorded.

FIXING—Making permanent the developed image in a film.

FLAT—A section of painted canvas, light board, or the like, used in building sets.

FLASH—A short scene, usually not more than three to five feet of film.

FLASH-BACK—A very short cut-back.

FOCAL LENGTH—The distance from the center of a simple thin lens to the image formed by it of a distant object.

FOOTAGE—Film length measured in feet.

FRAME—A single picture of the series on a motion picture film.

FRAME LINE—The dividing line between two frames.

INTERMITTENT SPROCKET—The sprocket which engages the film to give it intermittent movement at the picture aperture.

IRIS—An adjustable lens diaphragm.

IRISING—Gradually narrowing the field of vision by a mechanical device on the camera.

INSERT—Any photographic subject, without action, in the film.

INTERIOR—Any scene supposed to be taken inside a building.

JOINING—Splicing into a continuous strip (usually 1,000 feet) the separate scenes, titles, etc., of a picture.

LEADER—That piece of blank film attached to the beginning of the picture series.

LENS, SIMPLE—A lens consisting of but a single piece of glass or other transparent medium.

LENS, COMPOUND—The combination of a number of simple lenses.

LIGHT BEAM—A bundle of light rays which has a cross section of appreciable size.

LIGHT RAY—A stream of light of inappreciable cross section.

LOCATION—A place other than a studio selected for a motion picture scene.

MAGAZINE VALVE—The film opening in the magazine of a motion picture projector.

MASKS—Opaque plates of various sizes and shapes used in the camera to protect parts of the negative from exposure.

MOTION PICTURE—The representation of an object by the

rapid presentation to the eye of a series of pictures showing the object at successive intervals of time.

MULTIPLE-REEL—A photoplay of more than a thousand feet of film in length.

NEGATIVE—The developed film, after being exposed in a camera.

NEGATIVE STOCK—Light sensitive film intended for motion picture camera use.

OBJECTIVE—The simple or compound lens nearest an object which form an image of it.

OPAQUE PROJECTOR (often called "Post card projector")—lantern for optically projecting opaque objects, picture post cards, or the like.

OPTICAL AXIS—The straight line through the centers of the light source, lenses, diaphragm, etc., of an optical system, to which their planes are in general perpendicular.

PANORAM—To rotate a motion picture camera about an axis perpendicular to the tripod top.

PHOTOPLAY—A story in motion pictures.

POSITIVE—The developed film, after being printed from a negative.

POSITIVE STOCK—The light-sensitive film intended to be printed upon through a negative.

PRE-RELEASE—A picture not yet released for general public showing.

PRINT—Same as "positive."

PRODUCER—The maker of motion pictures.

PROJECTION DISTANCE—The distance between the projection lens and the surface upon which the image is focused.

PROJECTION LENS—The objective which forms upon the screen an image of the lantern slide, film, or other object under examination.

REEL—The flanged spool upon which film is wound.

REEL—An arbitrary unit of linear measure for film—approximately a thousand feet.

REGISTER—To superimpose exactly.

REGISTER—Any indication produced by simulation.

RELEASE—The publication of a moving picture.

REWIND—The process of reversing the winding of a film, usually so that the end to be first projected shall lie on the outside of the roll.

REWINDER—The mechanism by which rewinding is accomplished.

SCENE—The action taken at a single camera setting.

SCENARIO—A general description of the action of a proposed motion picture.

SCREEN—The surface upon which a picture is optically projected.

SHUTTER—A moving element, usually a disc, which intercepts the light in a motion picture apparatus one or more times for each frame.

Shutter—Working blade—(also variously known as the cutting blade, obscuring blade, main blade, master blade or travel blade). That sector which intercepts the light during the movement of the film at the picture aperture.

Shutter—Intercepting blade—(also known as the flicker blade). That sector which intercepts the light one or more times while the film is stationary.

SINGLE PICTURE CRANK (sometimes referred to as trick spindle)—A crank on a motion picture camera which makes one exposure at each complete revolution.

SLIDE (Stereo slide)—See "Lantern Slide."

SPLICING—Joining the ends of film by cementing.

SPOT—The illuminated area on the aperture plate of motion picture apparatus.

SPROCKET—The toothed cylinder which engages the perforations in the film.

STEREOPTICON—A lantern for projecting transparent pictures; i. e., lantern slides, often a double lantern for dissolving.

STILL—A picture without movement; e. g., a picture from a single negative.

TAKE-UP (noun)—The mechanism which receives and winds the film after it passes the picture aperture.

TAKE-UP (verb)—To wind up the film after it passes the picture aperture in motion picture apparatus.

THROW—See "Projection Distance."

TILT—To rotate a motion picture camera parallel to the direction of film motion and in a vertical plane through the optical axis.

TINTING—Coloring a film by dyeing the gelatine side of it.

TONING—Coloring a film by chemical action on the silver image.

TRICK CRANK—See "Single Picture Crank."

TRICK PICTURE—A motion picture intended to give the effect of action other than that which really took place.

TRAILER—That piece of blank film attached to the end of a picture series.

VISION—A new subject introduced into the main picture, by the gradual fading-in and fading-out of the new subject, as, for example, the visualization of a thought.

WORKING DISTANCE—The distance between an object and the nearest face of a lens forming an image of the object.

Special Report of the Committee on Standards

W. E. Story, Jr., *Chairman*

The Committee on Standards does not approve the submission at this time to the American Engineering Standards Society of the drawings entitled "Standards Safety Film" and "Professional Standard Film," prepared by the special committee appointed to confer with the Committee from the above Society, and submitted to the Committee on Standards for consideration.

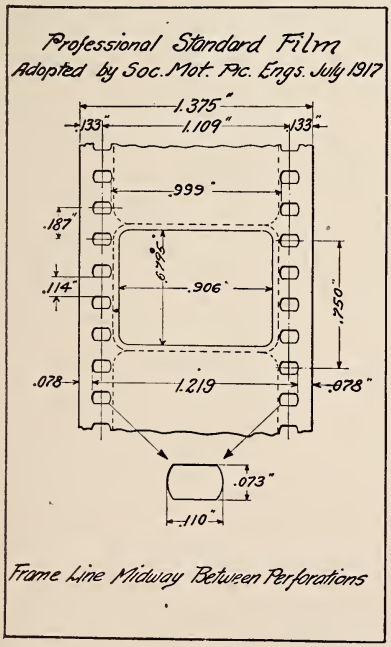
The Committee on Standards submits the following reasons for its position:

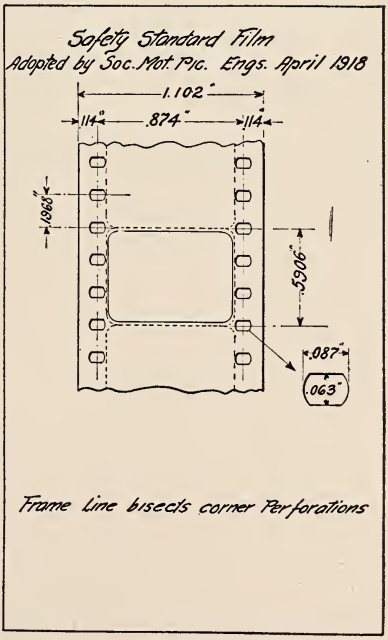
First—

The dimensions given in the drawing entitled "Standard Safety Film," are not those published in the transactions of May, 1920, but rather those in apparently universal use at present. According to the constitution, the dimensions of the drawing cannot be formally adopted by the Society as standards before its next meeting, at the very earliest. The Standards Committee cannot approve the submission of standards to other societies which have not been so adopted.

Second—

The addition of the word "Professional" in the title "Professional Standard Film" has not been authorized by the Society by tentative adoption at one meeting and formal acceptance at a subsequent meeting, as required by the constitution. The Standards Committee cannot approve the introduction of such limiting terms without such authorization.





Report of Committee on Resolutions

BE it resolved that the Society of Motion Picture Engineers extends to the officers now retiring its sincere appreciation and gratitude for their services to the organization. To Mr. Campe, our President, for the ability and energy that has been so large a factor in the rapid and satisfactory growth of the Society; to Mr. Mayer, our retiring Vice-President; to Mr. Victor, who as Secretary has given so untiringly of his time and enthusiasm, and to Dr. Kellner, Mr. Moulton and Mr. Porter for the unselfish services they have rendered the Society as members of the Board of Governors.

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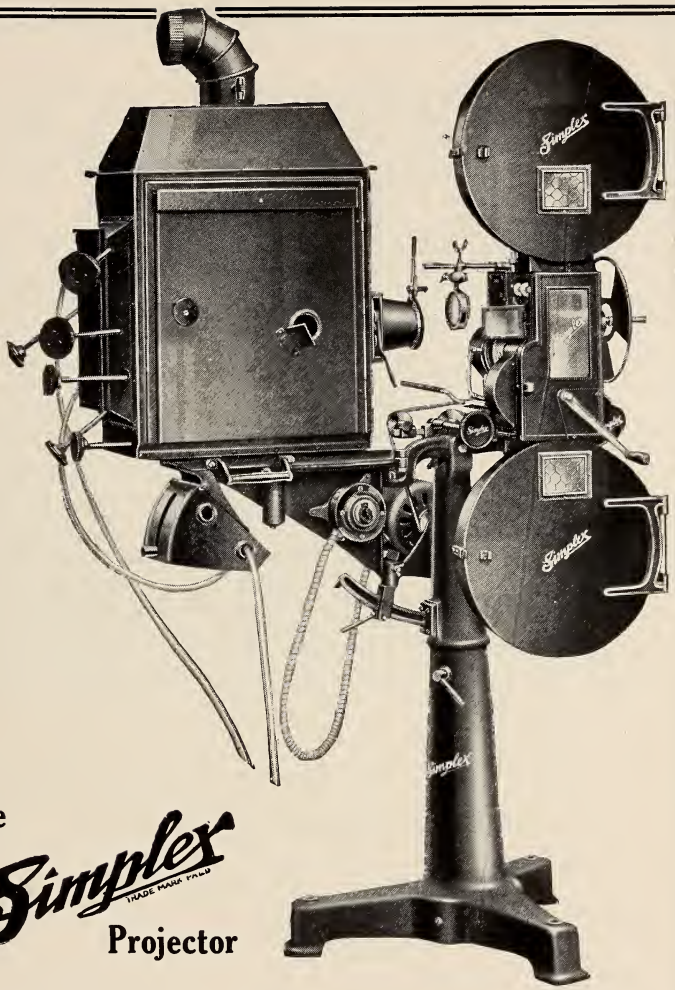

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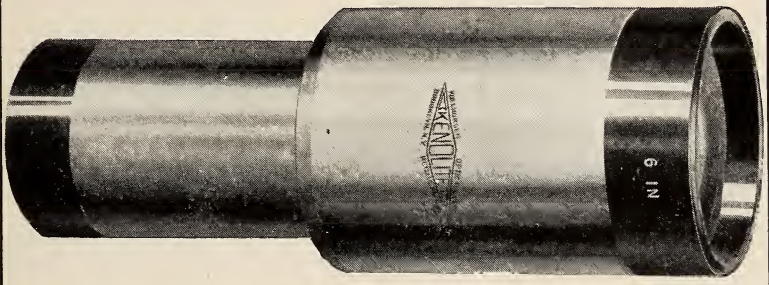

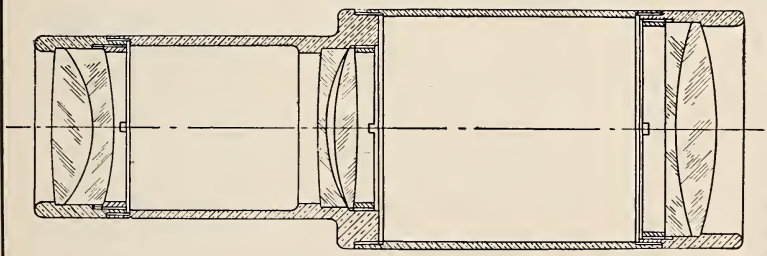

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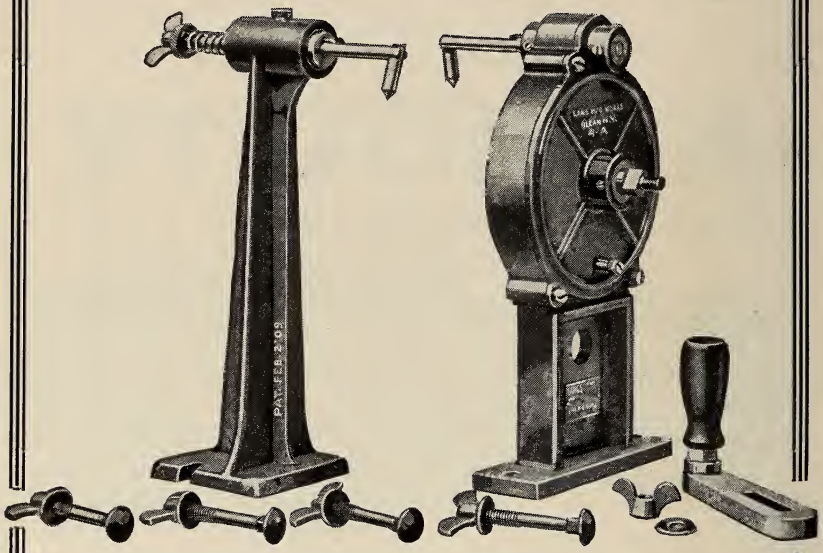

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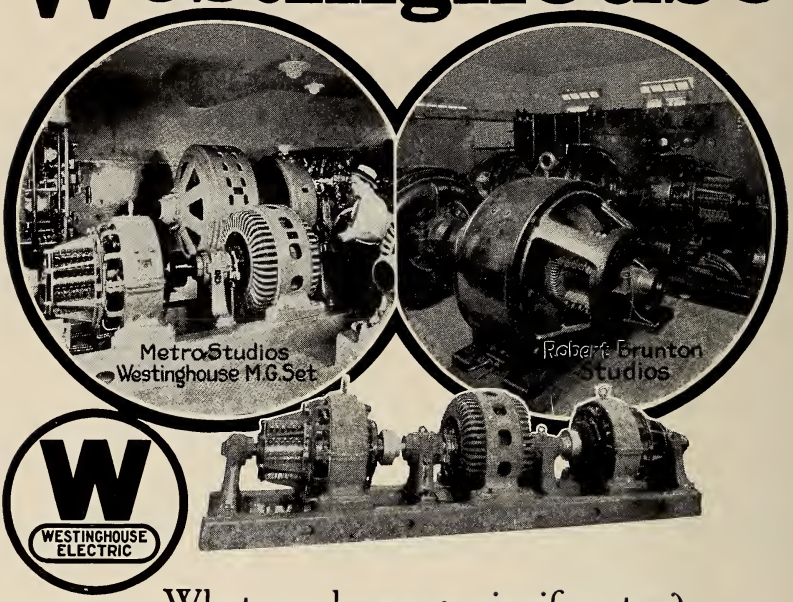

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